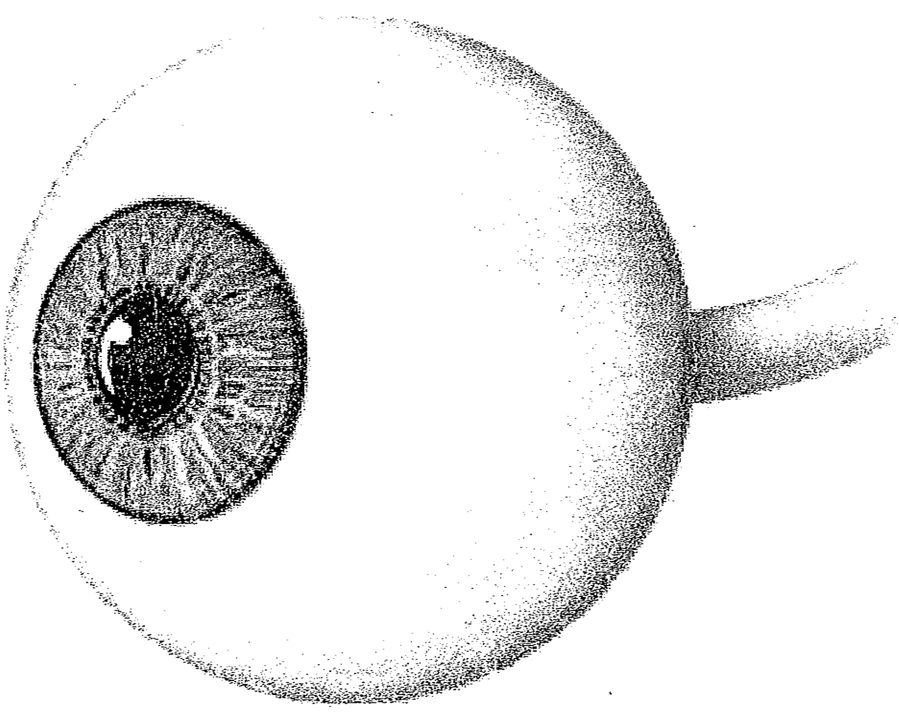
Anatomy of the eye

Mohamed Omar



Dear colleague,

I will be so thankful if I receive your advice, comment or any constructive criticism you have that may enable me to improve this work for our future colleagues.

E-mail: ***M.omar.ophth@hotmail.com***

Mohamed Omar

Embryology of the Eye

Derivatives of Embryonic Tissues :

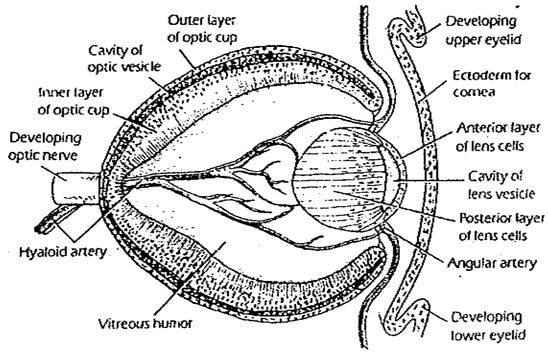
ECTODERM

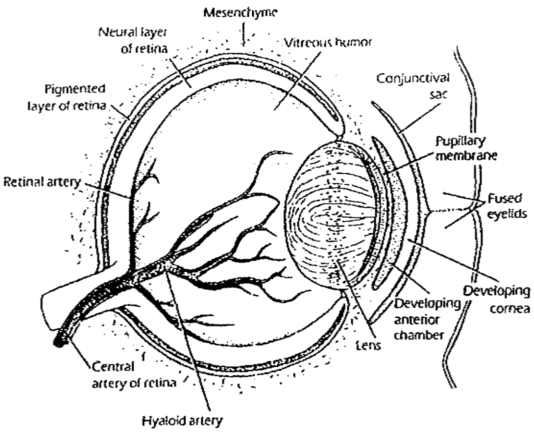
- *Neuroectoderm*
  - Retina → Sensory retina & RPE
  - Ciliary body → Ciliary epithelium (pigmented & nonpigmented)
  - Iris → Pigmented epithelium & Sphincter and dilator muscles
  - Optic nerve → Fibers & glia
  - Vitreous.
- *Neural crest cells*
  - Cornea → (stroma & endothelium)
  - Sclera (see also mesoderm)
  - Trabecular meshwork
  - Iris → Connective tissues & nonpigmented epithelium (melanophores)
  - Ciliary body → Ciliary muscles
  - Choroid → stroma
  - Melanocytes (uveal and epithelial)
  - Optic nerve → Meningeal sheaths.
  - Ciliary nerves → Schwann cells
  - Ciliary ganglion
  - Extraocular muscles → (Sheaths & Tendons)
  - All midline and inferior orbital bones, as well as parts of orbital roof and lateral rim
  - Cartilage
  - Connective tissue of orbit
  - Ocular and orbital vessels → Muscular layer & connective tissue sheaths
- *Surface Ectoderm*
  - Eyelids & caruncle → Epithelium, glands, cilia of skin
  - Cornea → epithelium
  - Conjunctiva → epithelium
  - Lens
  - Lacrimal gland & Lacrimal drainage system
  - Vitreous

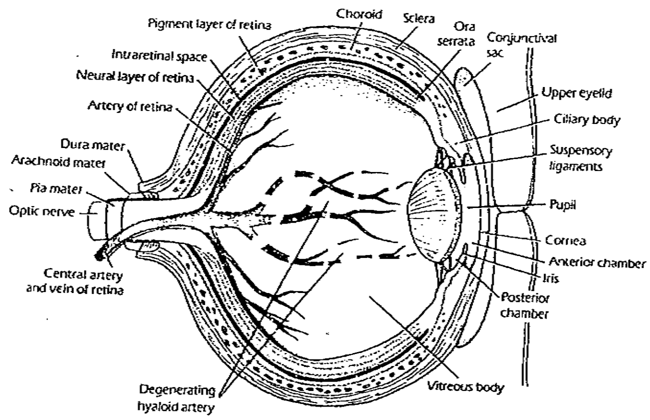
MESODERM

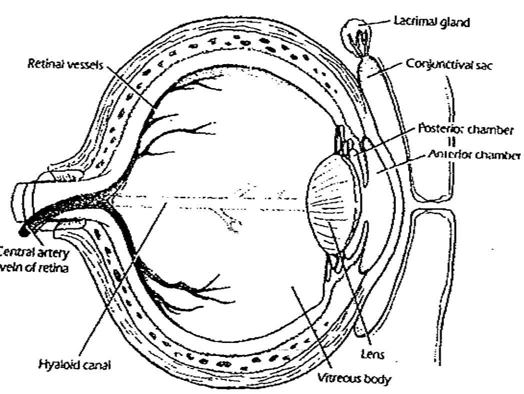
- Extraocular muscles → (fibers)
- Orbital and ocular blood vessels → Endothelial lining
- Sclera → Temporal portion
- Vitreous

Eye
in different
stages of
development



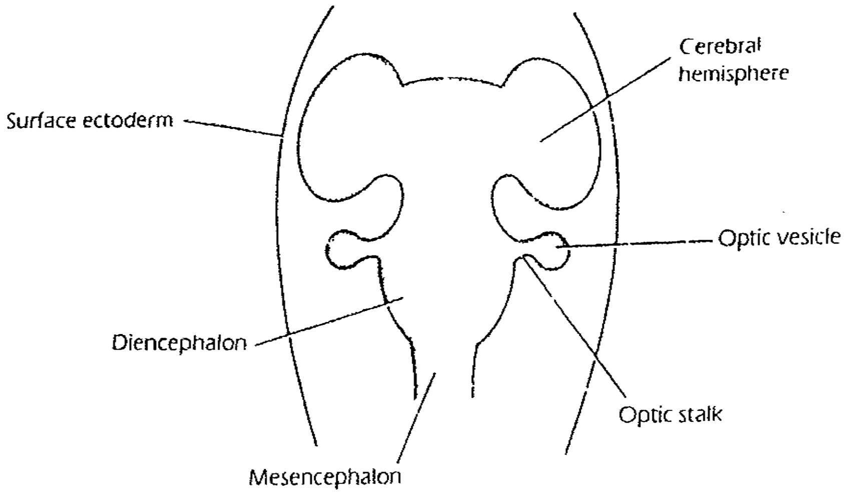


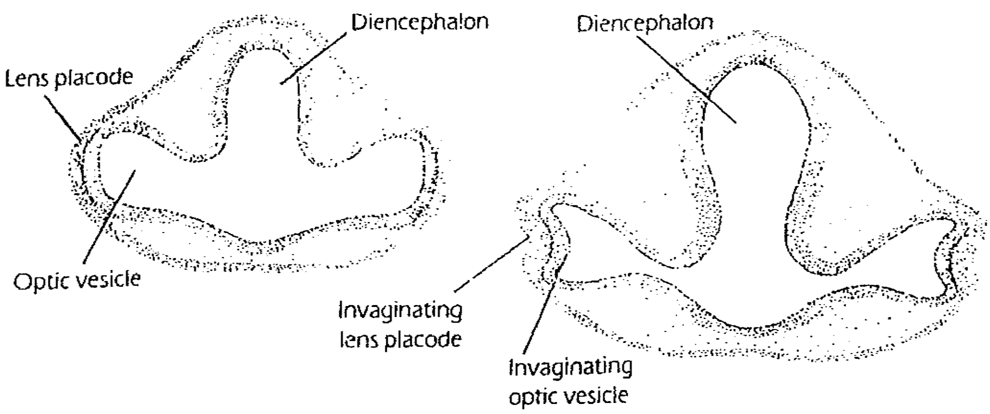


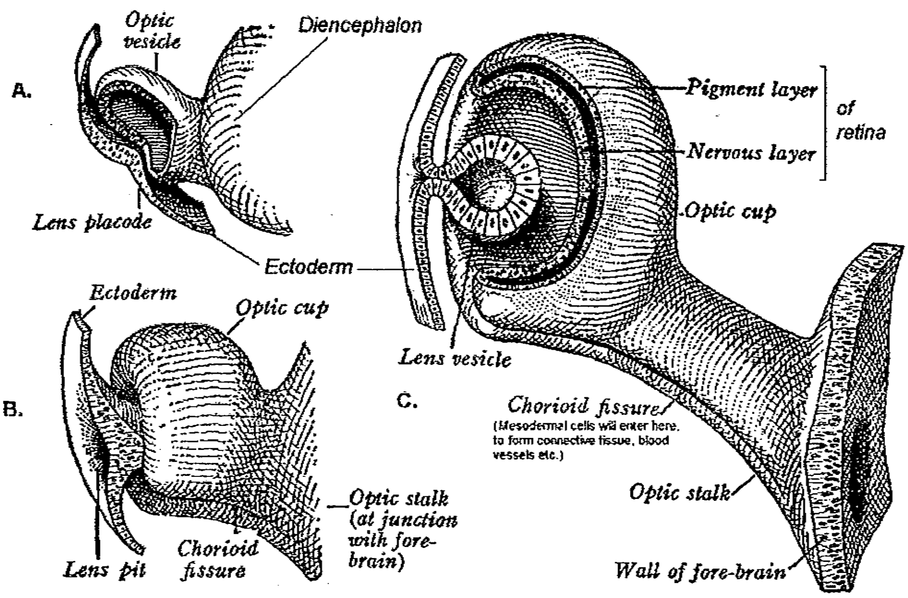


- **Neuroectoderm of the forebrain** → Retina, the nerve fibers of the optic nerve & the iris smooth muscle.
- **Surface ectoderm of the head** → Corneal and conjunctival ***epithelium***, the ***lens*** & lacrimal and tarsal ***glands***.
- **Mesenchyme in between** → ***corneal*** stroma, the ***sclera***, the ***choroid***, the iris, the ciliary musculature, part of the vitreous, and the cells lining the anterior chamber.
- **Neural crest** → The ***endothelium*** of the cornea

Optic vesicle → induces the development of the ***lens*** → induces the formation of the ***cornea*** & stimulates the development of the ***vitreous*** & is also important for the normal growth of the ***RPE*** → influences the differentiation of the mesenchyme into the ***choroid*** and the ***sclera***.


Cerebral hemisphere
Surface ectoderm
Optic vesicle
Diencephalon
Optic stalk
Mesencephalon


Diencephalon
Lens placode
Optic vesicle
Diencephalon
Invaginating lens placode
Invaginating optic vesicle


A.
Optic vesicle
Diencephalon
Lens placode
Ectoderm
B.
Ectoderm
Optic cup
Optic stalk (at junction with fore-brain)
Chorioid fissure
Lens pit
C.
Pigment layer
Nervous layer
of retina
Optic cup
Lens vesicle
Chorioid fissure
(Mesodermal cells will enter here, to form connective tissue, blood vessels etc.)
Optic stalk
Wall of fore-brain

The Eyeball

- <u>From the lateral aspect of the forebrain</u> an ectodermal diverticulum grows out laterally towards the side of the head.
  - Its **distal** portion becomes dilated → ***<u>Optic vesicle.</u>***
  - Its **proximal** portion becomes constricted → ***<u>Optic stalk.</u>***

- At the same time, <u>From the surface ectoderm</u>
  - A small area overlying the optic vesicle thickens → ***<u>lens placode</u>*** → invaginates & sinks below the surface ectoderm to form → ***<u>lens vesicle</u>***.

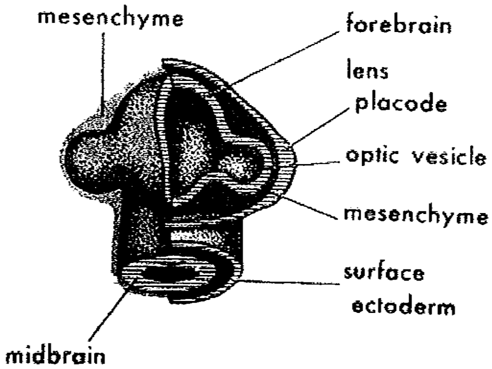
- The <u>optic vesicle</u> invaginates to form → ***<u>double-layered optic cup</u>***.
  - The inferior edge of the optic cup is deficient & this notch is continuous with a groove on the inferior aspect of the optic stalk called ***<u>Optic fissure</u>*** (choroidal fissure)
  - Vascular mesenchyme now grows into the optic fissure and takes with it the *hyaloid artery* → Growth of the margins of the fissure around the artery → the fissure closes (by 7^{th} week) → ***<u>optic canal</u>*** inside the optic stalk.
  - Failure of the fissure to close completely → **coloboma** formation which may include the <u>pupil</u>, <u>ciliary body</u>, <u>choroid</u> or <u>optic nerve</u>.

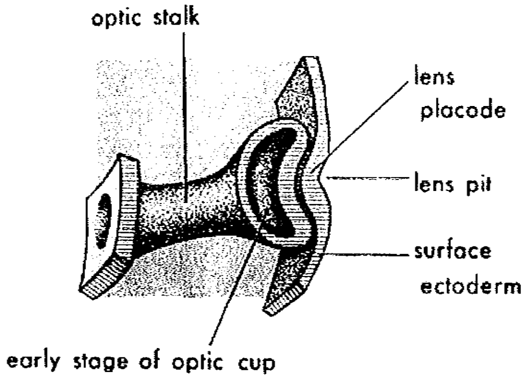
- By the 5^{th} week, the <u>lens vesicle</u> loses contact with the Surface ectoderm and lies within the mouth of the optic cup, the edges of which form the future pupil.

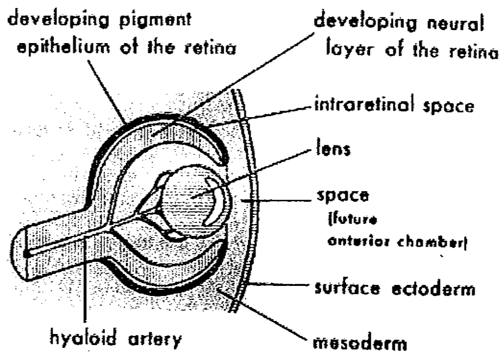
♣ Hyaloid Artery

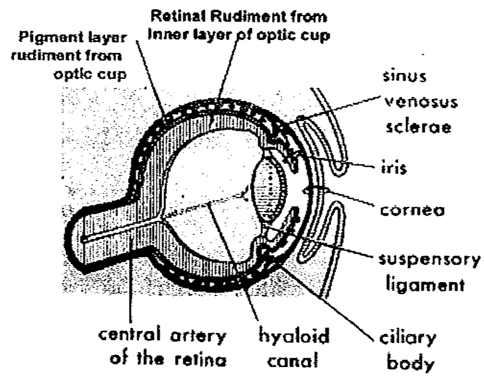
- Branch of ophthalmic artery
- Supplies:
  - Inner layer of optic cup
  - Mensenchyme of optic cup
  - Lens vesicle
- The hyaloid vessels are enclosed in the closing optic fissure
  → Distal portion ⇒ degenerates
  → Proximal portion ⇒ persists as CRA & CRV
- Persistant hyaloid artery
  - *Persistant small part of the distal portion → freely mobile, nonfunctioning cord projecting from the optic disc into the vitreous*
  - *Hyaloid cyst may be formed*
  - *The entire distal portion may be persisting extending from optic disc to the lens (the eye is usually microphthalmic)*

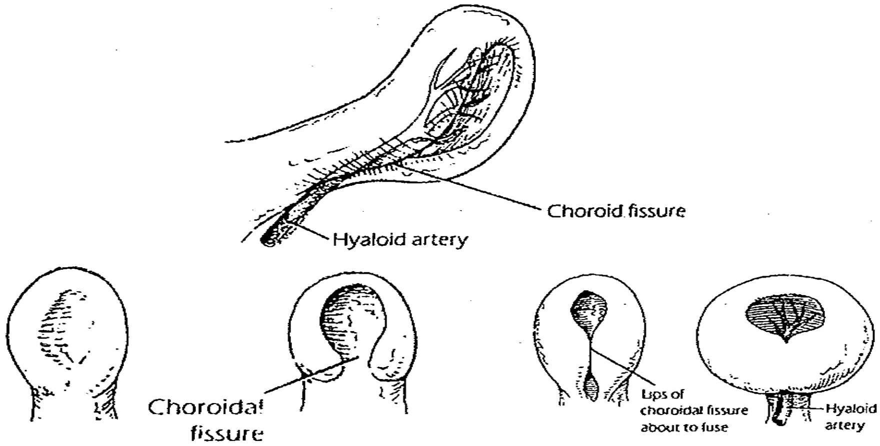
Optic cup formation of from **optic vesicle**











The Retina

From
(Neuroectoderm)

- **Retina** develops from the **optic cup**.
  - **Outer layer** of the optic cup (thin) → *RPE*
    [Initially, it is 4-6 cells thick (32 postovulation days), but with cytolysis of these cells the pigment epithelium becomes deeply pigmented and a single cell layer thick.] ⇒ firmly fixed to choroid
  - **Inner layer** of the optic cup (thick) →
    - Anterior 1/5 ⇒ persists as a layer of columnar cells, which, together with the pigmented epithelium of the outer layer, extend forward into the *posterior surface of the developing ciliary body and iris*
    - Posterior 4/5 ⇒ undergoes cellular proliferation, forming *Sensory retina*
      → outer nuclear zone ⇒ outer neuroblastic layer
        ⇒ Photoreceptors
        ⇒ Horizontal cells
        ⇒ Bipolar cells
      → inner marginal zone ⇒ inner neuroblastic layer (after invasion of the marginal zone by the nuclear zone cells)
        ⇒ Ganglion cells
        ⇒ Amacrine cells
        ⇒ Muller cells (bodies of its sustentaculur fibers)
    - The anterior 1/5 and posterior 4/5 are separated by *Ora serrata*.

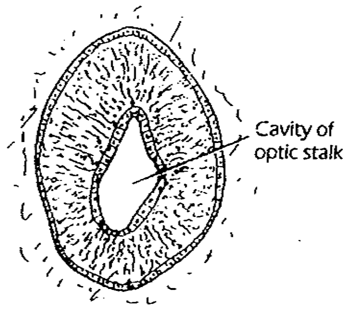
- *By 8th **month** of fetal life all the layers of the retina can be recognized.*
- *The retinal photoreceptor cells continue to form after birth so that the retina develops the ability of increasing resolution and sensitivity.*
- *The cavity of the optic vesicle is continuous through the optic canal with the cavity of the diencephalon (i.e., that part which will form the third ventricle)*
  → *Early in development, the outermost layer of cells of the nuclear zone have cilia, which are continuous with the ciliated ependymal cells of the third ventricle*
  → *Later, during the 7th **week** of development, the cilia of the cells of the nuclear zone disappear and are believed to be replaced by the outer segments of the rods and cones during the **4th month**.*

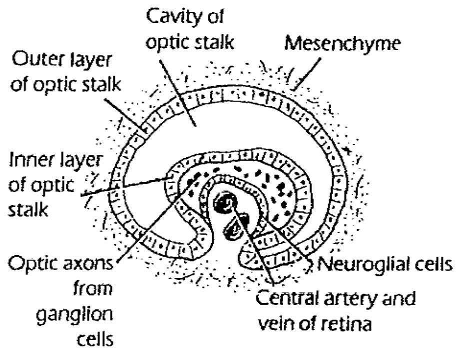
> *Applied anatomy:*
> ***Retinal detachment** doesn't involve detachment of the entire retina from its choroidal attachment (RPE is firmly adherent to choroid), but it involves detachment of the 2 layers of retina (RPE & sensory retina) that represent the previous outer and inner layers of optic cup.*

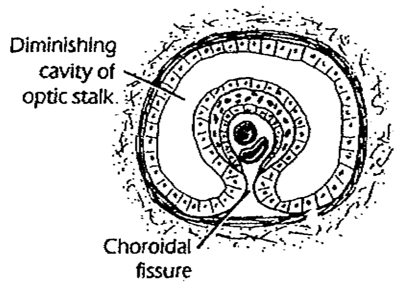
Congenital anomalies:

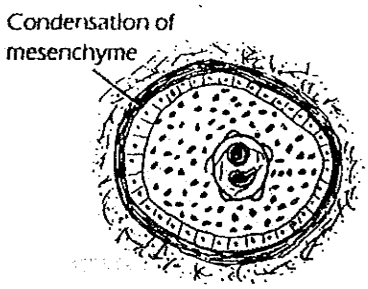
- *Coloboma of the retina: notched defect of the retina ⇒ caused by failure of closure of the optic fissure.*
- *Congenital Retinal detachment: due to failure of fusion of the 2 layers of the optic cup*
- *Absence of Pigment in the Retina and Iris → part of the syndrome of **Albinism**.*

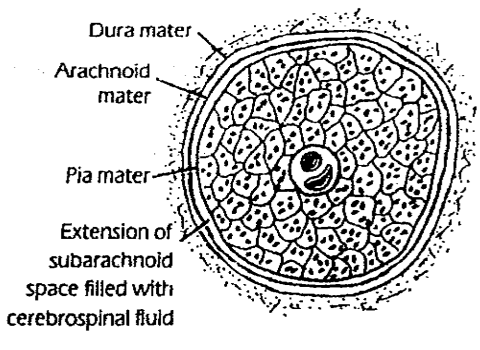
Optic nerve
formation of
from
optic stalk











□ **Macula :** ***Just after midterm*** ⇒ develops as a localized increase of superimposed nuclei in the ganglion cell layer, lateral to the optic disc.

□ **Fovea centralis :**

- *During the 7th month*
  - → Peripheral displacement of the ganglion cells, leaving a central shallow depression, the fovea centralis.
  - → The inner segments of the foveal cones become narrower & the outer segments become taller → increase in foveal cone density.
- *At birth*, the ganglion cells have been reduced to a single layer in the fovea.
- *By 4 months* of age there is no ganglion cells in the center of the fovea (the reason that newborn has imperfect central fixation is that cones are not fully developed until several months after birth)

□ **Optic disc :** Ganglion cells of the retina develop ***axons*** that ***converge*** to ***a point*** where the optic stalk leaves the posterior surface of the Optic cup. This site will later become the optic disc.

□ **Optic Nerve :** (**neuroectoderm** → axons + glia, **neural crest cells** → meningeal covering)

- *Fibers* → formed by axons of Ganglion cells in the superficial layer of the neural retina that grow proximally towards the brain in the wall of the optic stalk (among the cells that form the inner layer of the stalk)
- *glial cells* (supporting cells to the axons) → formed of the cells of the optic stalk
- The cavity of the stalk → disappears
- *Optic nerve sheath* → continuous with meninges of brain & sclera

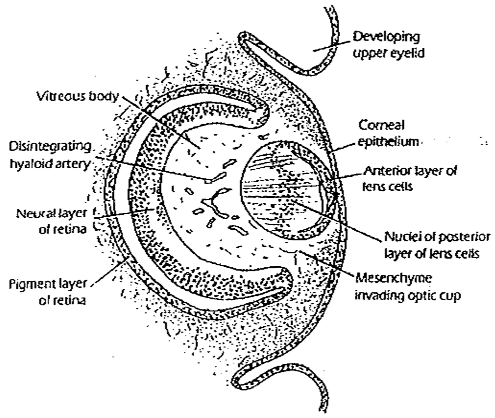
♣ *Myelination: The axons of the optic nerve begin to develop their myelin sheaths just before birth, but the process of myelination continues for some time after birth. (completed 10 weeks after the eye have been exposed to light)*

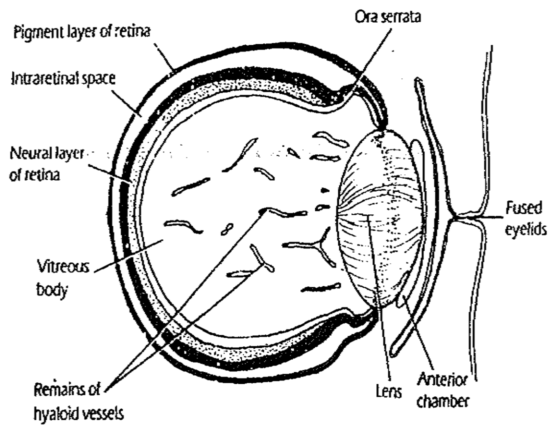
♣ *The partial decussation of the axons of the two optic nerves →* ***Optic chiasma*** *→ The optic nerve axons leave the optic chiasma & grow backward as the →* ***Optic tracts*** *and the majority pass to the lateral geniculate body and to the tectum of the midbrain.*

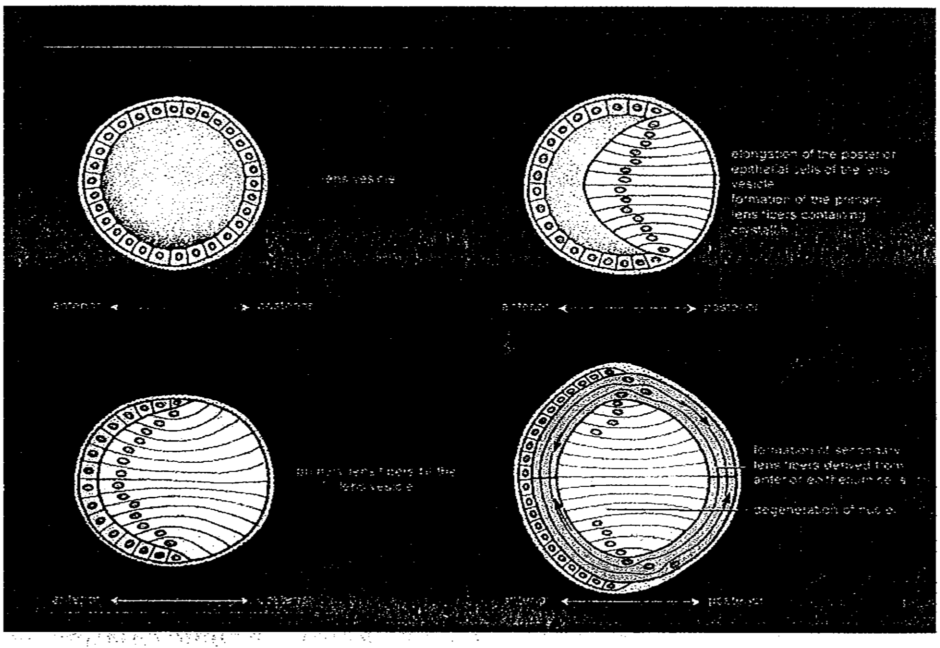
♣ *The Proximal end of hyaloid artery and vein become the* ***central artery and vein*** *of the retina. (the distal degenerates → hyaloid canal)*

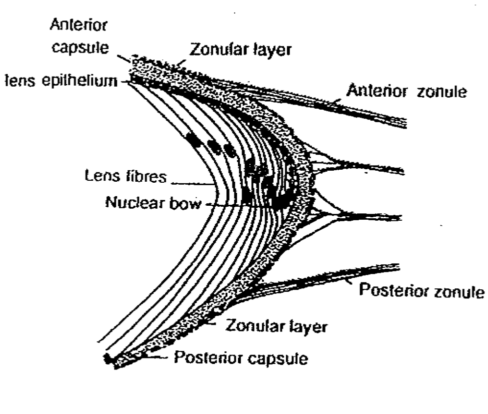
Applied anatomy:
The subarachnoid space around the brain extends around the optic nerve as far as its attachment to the eye ⇒ An increase of CSF pressure → compresses the optic nerves → interrupt axonal transport + slows venous return from the eye → Papilloedema.

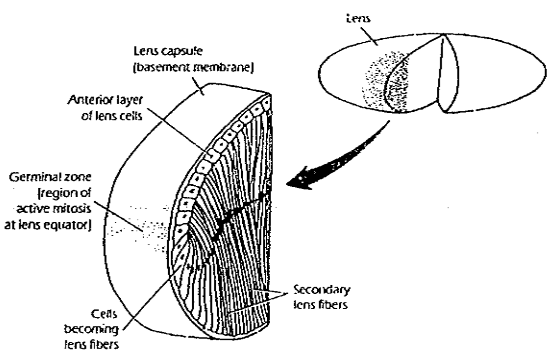
Lens Development











The Lens

From
(Surface ectoderm)

☐ Steps of development (induced by signal produced by the optic vesicle)

Thickening of surface ectoderm overlying the optic vesicle → ***lens placode*** → invaginates & sinks below the surface ectoderm to form → ***lens vesicle***. (which consists of a central cavity surrounded by a single layer of cells, covered by a basal lamina, surrounded by vascular membrane)

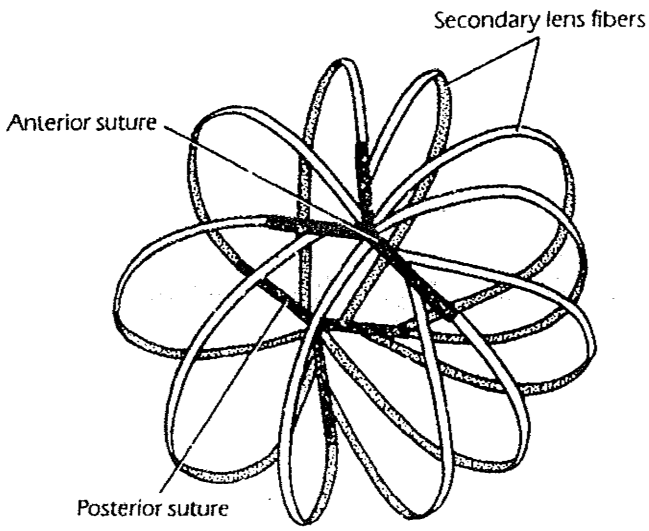
1) **Cells** differentiation depends on their place:

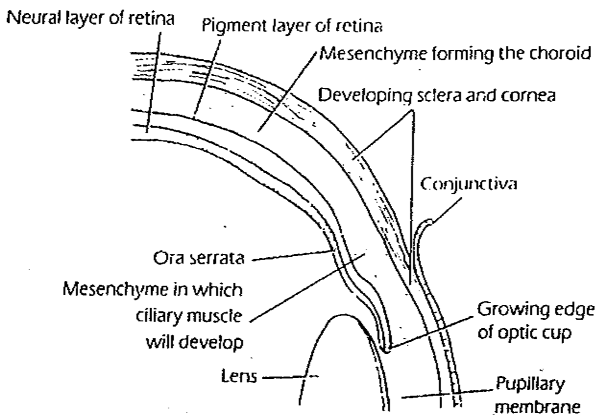
- **At the anterior wall of the vesicle**
  - Formed of **cuboidal epithelium** → *Anterior lens epithelium*.
- **At the posterior wall of the vesicle**
  - Formed of **tall columnar cells** → Rapidly *elongate* and *become filled with proteins* called crystallins (make them transparent) → *1^{ry} lens fibers*. (last a life time)
    - The **base** of each 1^{ry} lens fiber remains attached to the basal lamina posteriorly while the **apices** grow forward towards the anterior lens epithelium → the cavity of the lens vesicle gradually becomes obliterated
    - The **nuclei** of the lens fibers
      → *move* anteriorly within the cells to form a line convex forward called the **nuclear bow** *(Formed by anterior migration of lens fibers nuclei)*
      → then nuclei *disappear*.
- **At the equatorial zone**
  - Anterior epithelial cells (cuboidal) at the equator undergo mitotic division, elongate & lose their nuclei → *2^{ry} lens fibers*. (continue to grow & increase)
    - The **basal** ends of the fibers remain attached to the basal lamina. while their **apical** ends added concentrically around the primary fibers → Laminated appearance on cut section.
    - The increase in the *equatorial diameter* & *enlargement* of the lens with age is because of the continued production & persistence of new ***secondary lens fibers*** Throughout life.
    - The increase in the *density* during development is because ***successive fibers become tightly apposed & the layers become interdigitated.***

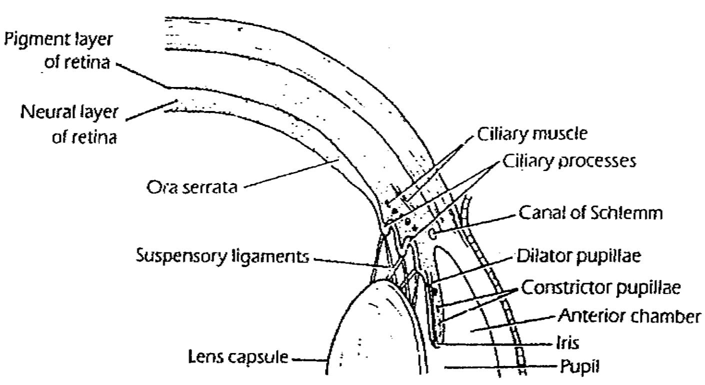
2) **The Lens Capsule** *(The true lens capsule)*
- Non-cellular envelope that completely surrounds the lens.
- Formed from the ***thickened basal lamina*** developed from the lens epithelium.

3) **Tunica vasculosa lentis** *(The vascular lens capsule)*
- Vascular mesenchymal layer investing the lens (supplied by hyaloid artery)
- Responsible about rapid growth of the lens during embryonic life.
- The anterior portion of this capsule is called → ***pupillary membrane***.

⇒ The **tunica vasculosa lentis** & **pupillary membrane** disappear during late fetal life due to degeneration of the part of the hyaloid a. supplying them.


Secondary lens fibers
Anterior suture
Posterior suture


Neural layer of retina
Pigment layer of retina
Mesenchyme forming the choroid
Developing sclera and cornea
Conjunctiva
Ora serrata
Mesenchyme in which ciliary muscle will develop
Growing edge of optic cup
Lens
Pupillary membrane


Pigment layer of retina
Neural layer of retina
Ora serrata
Ciliary muscle
Ciliary processes
Canal of Schlemm
Suspensory ligaments
Dilator pupillae
Constrictor pupillae
Anterior chamber
Iris
Lens capsule
Pupil

□ **Lens sutures**

- **<u>Erect</u> anterior** Y-shaped suture: Apex to apex apposition of the corresponding lens fibers from the 2 opposite sides near the anterior pole.
- **<u>Inverted</u> posterior** Y-shaped suture: Base to base apposition of the detached lens fibers near the posterior pole.

□ **Blood supply**

- The developing lens → ***<u>Hyaloid artery</u>***
- Thereafter → it depends on diffusion from ***<u>aqueous humour</u>*** & ***<u>vitreous</u>***

□ **The <u>Suspensory ligament</u> of the Lens**

- The <u>mesenchyme</u> (situated at the edge of the optic cup) → ***<u>Lens zonule</u>***

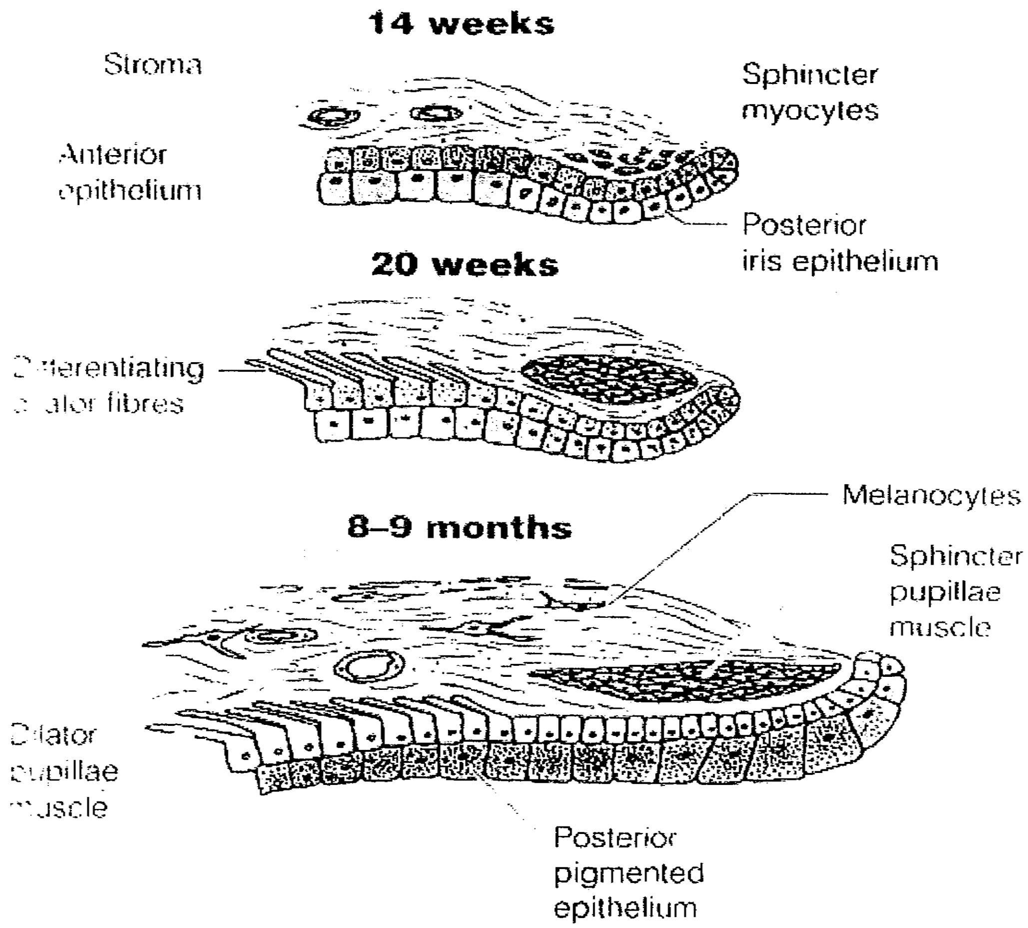
Congenital anomalies

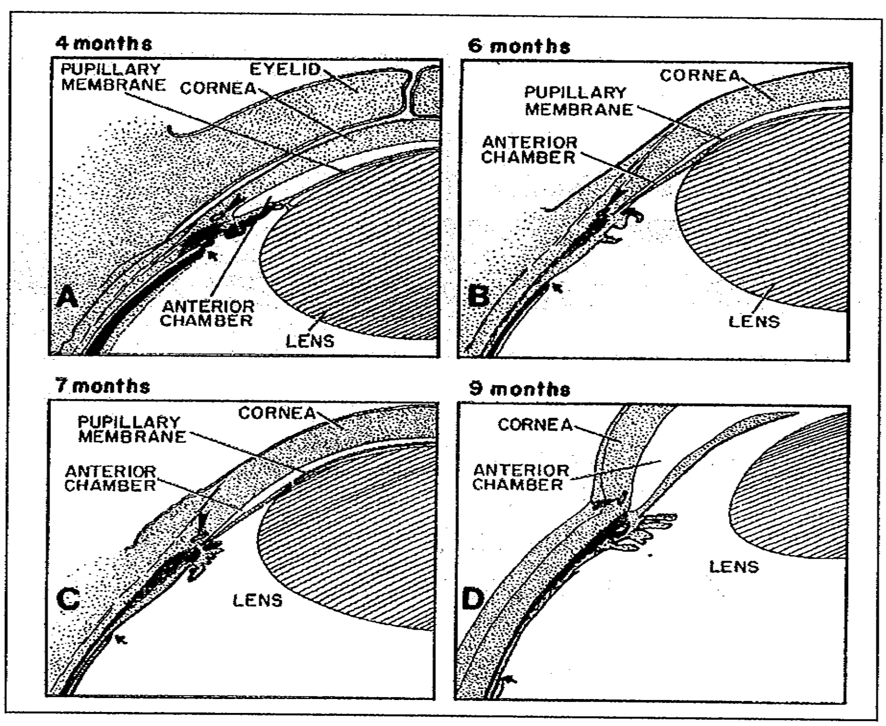
- ***<u>Congenital cataract</u>***
- ***<u>Congenital aphakia</u>*** *Due to failure of development of lens placode during the 4^{th} month (caused by failure of its induction by optic vesicle)*
- ***<u>Ectopia lentis</u>***

Ciliary Body

From
(Mesoderm + Neuroectoderm)

- The <u>mesenchyme</u> (situated at the edge of the optic cup) →
  - ***<u>Connective tissue of the ciliary body</u>***.
  - ***<u>Ciliary muscle</u>***.
- The <u>Neuroectoderm</u> of the optic cup
  - Outer layer of optic cup (continuous with RPE) →
    - ***<u>Pigmented ciliary epithelium</u>***.
  - Inner layer of optic cup (its anterior 1/5) →
    - ***<u>Nonpigmented ciliary epithelium</u>***.
      (represents anterior prolongation of neural retina in which no neural element differentiate)


14 weeks
Stroma
Sphincter myocytes
Anterior epithelium
Posterior iris epithelium
20 weeks
Melanocytes
8–9 months
Sphincter pupillae muscle
Posterior pigmented epithelium


4 months
PUPILLARY MEMBRANE
EYELID
CORNEA
A
ANTERIOR CHAMBER
LENS
6 months
CORNEA
PUPILLARY MEMBRANE
ANTERIOR CHAMBER
B
LENS
7 months
PUPILLARY MEMBRANE
CORNEA
ANTERIOR CHAMBER
C
LENS
9 months
CORNEA
ANTERIOR CHAMBER
D
LENS

The Iris

From
(Mesoderm + Neuroectoderm)

- The **mesenchyme** situated on the anterior surface of the lens condenses to form the pupillary membrane
  → ***Vascular CT of the iris***

- The two layers of the **neuroectoderm** forming the edge of the optic cup, (that have covered the ciliary muscle) extend onto the posterior surface of the pupillary membrane
  → ***Iris Epithelium*** *(Anterior & Posterior)*
  → ***Dilator & Sphincter pupillae muscles*** (from Anterior epithelium)
  → ***Chromophores*** = ***Melanophores*** (pigment cells derived from the neuroectoderm penetrate the sphincter muscle and enter the connective tissue.)

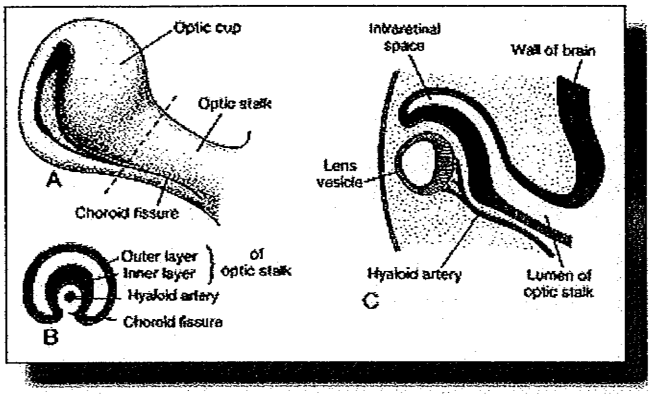
- Pupil
  → Early, the pupillary membrane is **attached** to the edge of the pupil.
  → Later, the pupillary membrane begins to **separate** from the iris but remains attached to the front of it.
  → At about the 8th month the central part of the pupillary membrane starts to **degenerate** and eventually **disappears** as far as its attachment forming → *Collarette*
  → After birth, part of the membrane may persist as strands of connective tissue that stretch across the pupil. ⇒ Persistant pupillary membrane.

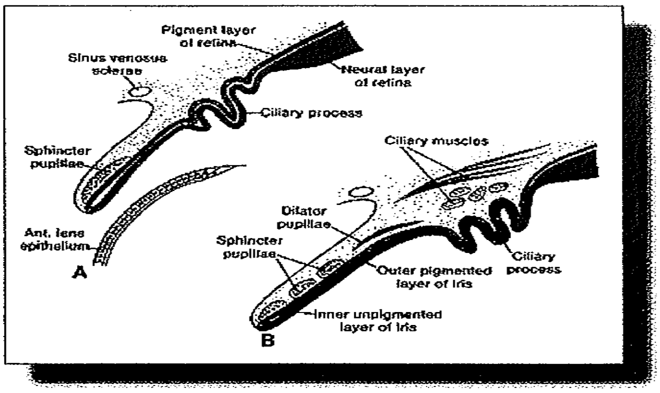
♣ Colour of the iris:

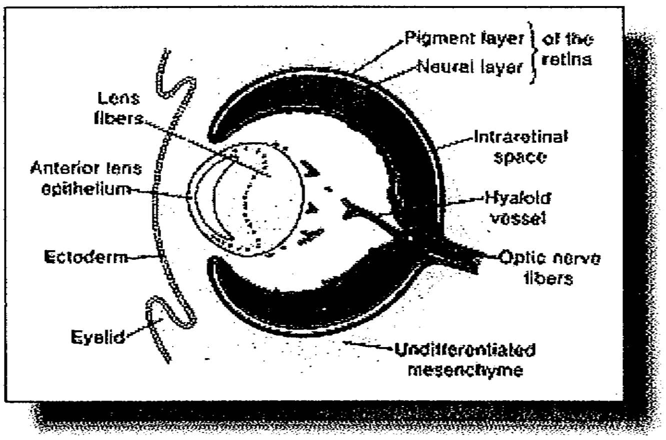
- Depends on concentration and distribution of chromophores (pigment containing cells) in the spongy, vascular, loose C.T of the iris
  → If melanin pigment is ***confined to the epithelium*** on the post surface of the iris → Eye ⇒ **blue**
  → If melanin pigment is ***distributed throughout the stroma*** of the iris → Eye ⇒ **Brown**
- In most infants ⇒ bluish, but it acquires its definitive color during the 1st few months as pigmentation occurs.

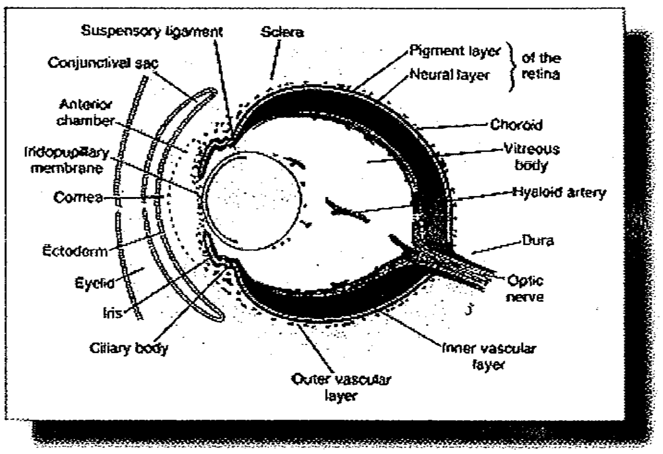
Congenital anomalies :

- ***Coloboma of the iris:*** *Notched defect of a sector of the iris ⇒ Due to failure of closure of the optic fissure.*
- ***Persistant pupillary membrane:*** *part of the pupillary membrane may persist as strands of CT that stretch across the pupil. (If the entire pupillary membrane persists →* ***Congenital atresia of the pupil****)*
- ***Congenital Aniridia:*** *Complete absence of the iris ⇒ due to arrest of development at the rim of the optic cup during the 8th week*


Optic cup
Optic stalk
A
Choroid fissure
Outer layer
Inner layer
of optic stalk
Hyaloid artery
Choroid fissure
B
Intraretinal space
Wall of brain
Lens vesicle
Hyaloid artery
Lumen of optic stalk
C


Pigment layer of retina
Sinus venosus sclerae
Neural layer of retina
Ciliary process
Sphincter pupillae
Ant. lens epithelium
A
Ciliary muscles
Dilator pupillae
Sphincter pupillae
Ciliary process
Outer pigmented layer of iris
Inner unpigmented layer of iris
B


Pigment layer
Neural layer
of the retina
Lens fibers
Anterior lens epithelium
Intraretinal space
Hyaloid vessel
Ectoderm
Optic nerve fibers
Eyelid
Undifferentiated mesenchyme


Suspensory ligament
Sclera
Conjunctival sac
Pigment layer
Neural layer
of the retina
Anterior chamber
Choroid
Iridopupillary membrane
Vitreous body
Cornea
Hyaloid artery
Dura
Ectoderm
Eyelid
Optic nerve
Iris
Ciliary body
Inner vascular layer
Outer vascular layer

The Anterior and Posterior Chambers

- The **anterior chamber** arises as a slit in the mesenchyme between the *surface ectoderm* and the *developing iris*.
- The **posterior chamber** develops as a split in the mesenchyme posterior to the *developing iris* and anterior to the *developing lens*.

⇒ The anterior and posterior chambers communicate when the pupillary membrane disappears and the pupil is formed.

The Vitreous Body

The vitreous body develops between the lens and the optic cup.

- The **primitive** or **primary** or **hyaloid** vitreous
  - Derived partly from the ***surface ectodermal cells*** of the developing lens and partly from the ***neuroectoderm*** of the inner layer of the optic cup.
  - Formed of Protein rich material + vascularized mesoderm that enters the optic fissure (hyaloid system) ⇒ ***Mesenchymal***
  - Later, the hyaloid vessels atrophy and disappear, leaving the acellular hyaloid canal.

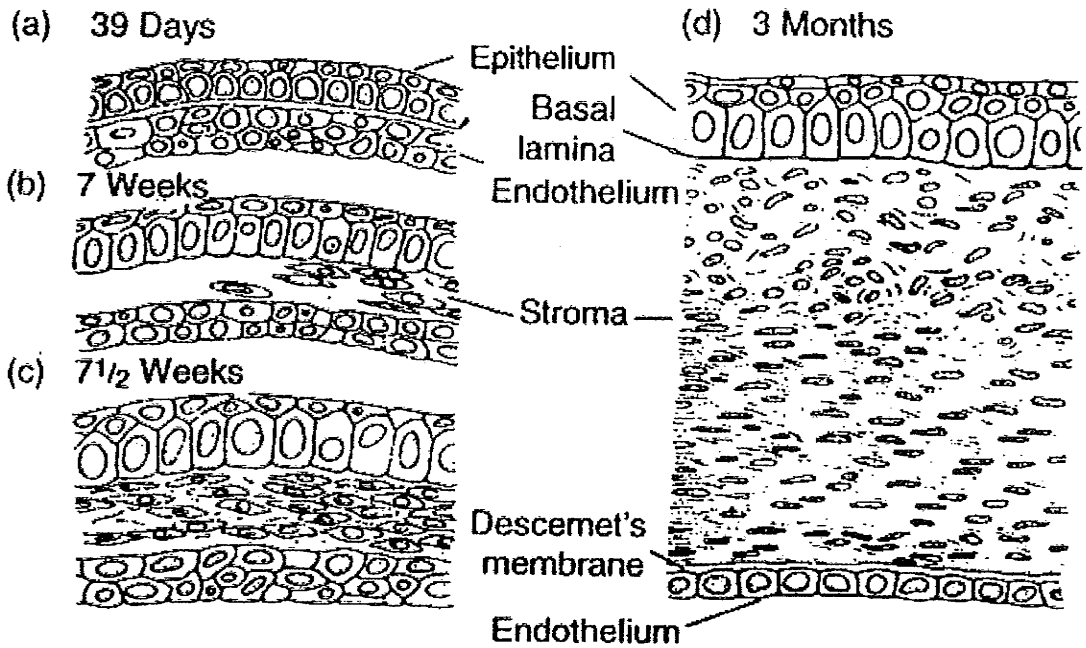
→ The primary vitreous begins with protein-rich PAS positive material that forms between the lens placode and optic vesicle about the 36th postovulation day.

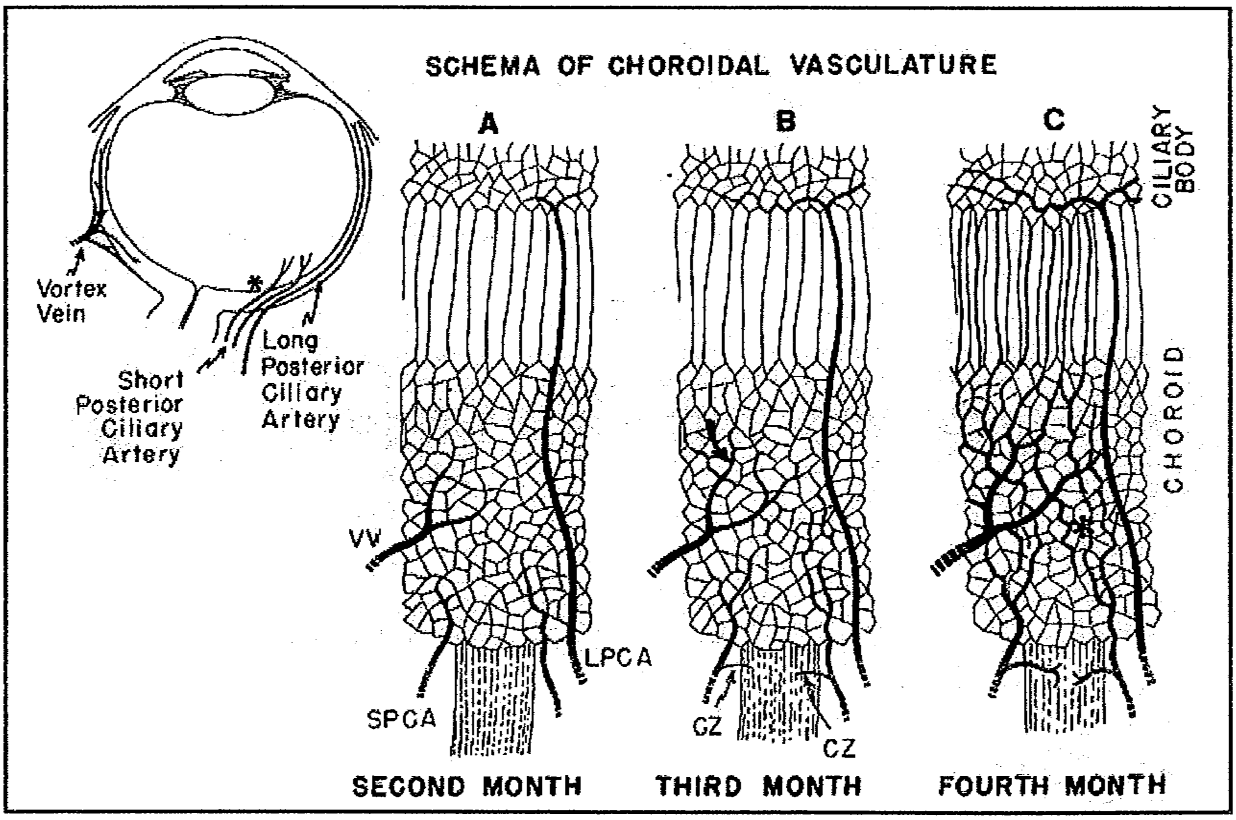
→ Vascularized mesoderm enters the optic fissure, and by the 7th **week** the hyaloid artery is developed and reaches the lens.

→ By the 9th **week** the hyaloid system is → fully developed
- about the 5th **month** → begins to resorb
- after the 7th **month** → no longer caries blood
- after birth → absent except for its remnant (the canal of Cloquet)

- The **definitive** or **secondary** vitreous
  - **Neuroectodermal** origin.
  - Appears about the 7th **week** as the retinal fissure closes
  - Arises between the primitive vitreous and the retina & gradually fills the vitreous cavity as the hyaloid system resorbs.

- The **tertiary** vitreous
  - **Mesenchymal** origin.
  - It is the Zonule of Zinn
  - Begins to form in the **6th month.**
  - Extend between the ciliary processes and the lens capsule.


(a) 39 Days
(b) 7 Weeks
(c) 7½ Weeks
(d) 3 Months
Epithelium
Basal lamina
Endothelium
Stroma
Descemet's membrane
Endothelium


SCHEMA OF CHOROIDAL VASCULATURE
Vortex Vein
Short Posterior Ciliary Artery
Long Posterior Ciliary Artery
A
B
C
CILIARY BODY
CHOROID
VV
SPCA
LPCA
CZ
CZ
SECOND MONTH
THIRD MONTH
FOURTH MONTH

The Cornea

The formation of the cornea is <u>induced</u> by the **<u>lens</u>** and the **<u>optic cup</u>**

- Surface ectoderm → ***<u>Corneal epithelium</u>*** (stratified Squamous Non-keratinized)
- Mesenchyme → ***<u>Bowman's membrane</u>***
- Mesenchyme → ***<u>Substantia propria</u>***
- Neural crest → ***<u>Corneal endothelium</u>*** + ***<u>Fibroblasts</u>*** *(that produce the entire stroma)*

<u>Descemet's membrane</u>, → synthesized by the endothelial cells.

The Sclera

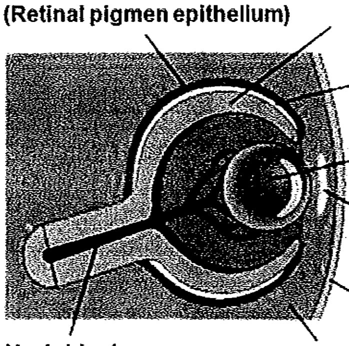
- Formed from a ***<u>condensation of the secondary mesenchyme</u>*** (neural crest cells + mesodermal cells) surrounding the *<u>optic cup</u>*
- It <u>starts anteriorly</u> (near the future insertion of the rectus muscles) then extend posteriorly, so that it envelops the globe by the 5th month.

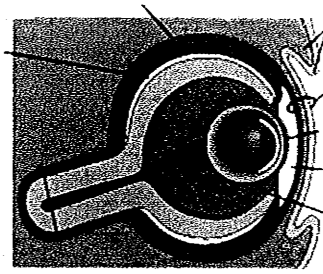
♣ The sclera is continuous with → Dura mater of the brain (at the attachment of optic nerve to the eye)

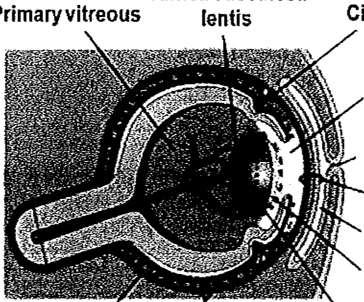
The Choroid

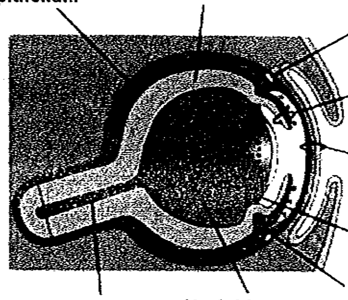
- Formed from the ***<u>secondary mesenchyme</u>*** surrounding the *<u>optic vesicle</u>*
  - ***<u>Mesoderm</u>*** → <u>Blood vessels</u>.
  - ***<u>Neural crest cells</u>*** → <u>melanophores</u> + <u>pericytes</u> + <u>CT</u>.

♣ The choroid is continuous with → Pia & arachnoid mater of the brain.


Outer layer of optic cup
(Retinal pigmen epithelium)
Inner layer of optic cup
(Neuro-retina)
Intra-retinal
space
Lens
Space (Future
anterior chamber)
Surface ectoderm
Hyaloid artery
Mesoderm


Escle Sclera
Eyelid
Intra-retinal
space
Cornea
Pupillary membrane
Anterior
Chamber
Posterior
Chamber


Tunica Vasculosa
lentis
Primary vitreous
Ciliary body
Anterior Chamber
Palpebral opening
Cornea
Conjunctival sac
Lens epithelium
Sclera
Vascular plexus
Of the choroid
Equatorial Zone
Of the lens


Retinal pigmen
epithelium
Neuro-retina
Sinus
Venosus
Sclerae
Iris
Cornea
Suspensory
Ligament of
The lens
Ciliary body
Central retinal artery
Hyaloid canal

The Eyelids & The Conjunctiva

(Surface ectoderm → Skin + cilia + glands + conjunctiva)
(Mesenchyme → Tarsus + Orbicularis oculi muscle)

- **The Eyelids:**
  - Formed of 2 folds of *surface ectoderm* containing *core of mesoderm*.
  - The two eye lids unite with each other at about **10^{th} week** The lids remain fused until about the 5^{th} mouth, when they start to separate. Separation of the eyelids is complete by the 7^{th} month.(at about **26^{th} week**)

- **The Conjunctiva:** While the lids are fused, a closed space, the ***conjunctival sac***, exists in front of the cornea. → when the eyes open, the conjunctiva covers the sclera & lines the eyelids.

- **Eyelashes** + **glands** (Meibomian, Moll & Zeis) → develop from the *surface ectoderm*.

- **Tarsal plates** + **Connective tissue** → develop from the *mesenchyme* at core of the lids.

- **Orbicularis oculi muscle** → develops from the *mesenchyme of the 2^{nd} pharyngeal arch* (Facial n.)

Congenital anomalies:

- *Cleft Eyelid (eyelid coloboma): A notched defect usually occurs in the upper lid, If the cornea is left exposed when the eyes are closed, the defect must be surgically closed at once.*
- *Adhesion of Eyelid Margins: Rarely, the eyelid margins are connected by bands of tissue that reduce the palpebral fissure and impair the mobility of the eyelids. Microscopically, the bands have a core of CT and are covered on the outside with epithelium.*
- *Congenital ptosis : Due to abnormal development of Levator palpebrae superioris muscle or superior division of occulomotor nerve (usually associated with failure of normal development of SR)*
- ***Cryptophthalmos (hidden eye) : Due to failure of the eyelids to develop***

The Lacrimal Gland

From
(Ectoderm forming the conjucntival surface)

- Formed as a series of ***ectodermal buds*** that grow superolaterally from the superior fornix of the conjunctiva into the underlying mesenchyme.
- Later, the buds ***canalize***, forming the **secretory units & multiple ducts** of the gland.
- The gland becomes ***divided*** into orbital and palpebral parts with the development of the *levator palpebrae superioris*.
- Tears are not produced until the 3rd month after birth → the newborn is not tearing while crying.

The Lacrimal Sac & Naso lacrimal Duct

- Formed as a *solid cord of ectodermal cells* in a cleft between the lateral nasal process & the maxillary process of the developing face.
- Later, the cord ***canalizes*** to form → **nasolacrimal duct.**
(Incomplete canalization, particularly in the lower end of the NLD is common, even in full term infants)
- The Superior end becomes ***dilated*** to form → **lacrimal sac.**
- ***Further cellular proliferation*** results in the formation of **lacrimal ducts** which enter each lid.
(Lacrimal puncta don't open into the eyelid margins till just before the lid margins separate at the 7th month)

Congenital anomalies:

Atresia of the Nasolacrimal Duct → *watering from the affected eye and liability to infection of the lacrimal duct and sac. it may occur at the upper end, but it usually occurs at the lower end, at the entrance into the nose.*

Congenital Fistulas of the Lacrimal Sac → *The orifice is usually found on the side of the nose a short distance below the inner canthus of the eye.*

The Extraocular Muscles

- Formed from the ***mesenchyme*** in the region of the developing eye ball.
    - ***Mesoderm*** → muscles fibers.
    - ***Neural crest cells*** → Tendons & sheathes.
- At first they are a single mass of mesenchyme → later separate into distinct muscles first at their insertions and later still at their origins.
- The levator palpebrae superioris is formed last, splitting off from the mesenchyme that forms the superior rectus muscle.
- During development they become associated with the 3^{rd}, 4^{th}, & 6^{th} cranial nerves.

The Orbital Bones

- Develop from the ***mesenchyme*** that encircles the optic vesicle.
    - The medial wall forms from → the lateral nasal process.
    - The lateral wall and inferior wall from → the maxillary process.
    - The superior wall from → the mesenchymal capsule of the forebrain.
    - Posteriorly, the orbit is formed of the bones of the base of the skull.
- The bones of the orbit form ***in membrane*** except those belonging to the base of the skull which develop ***in cartilage***.
- Initially, the optic axes are ***directed laterally*** towards the side of the head; only later on they are ***directed anteriorly***.
- Early in development the ***eyeball develops at a faster rate than the orbit***, so that in the sixth month of fetal life the anterior half of the eyeball projects beyond the orbital opening.

Postnatal Growth

- The **eyeball** increases rapidly in size during the first years of life. The rate of growth then slows but increases again at puberty.
- The **cornea**, which is relatively large at birth, reaches adult size by 2 years old.
- Pigmentation of the **iris** stroma occurs during the first years after birth, so that usually the color of the iris changes by a deepening coloration.
- The **lens** grows rapidly after birth and continues to grow throughout life. At birth the eye is hypermetropic. Later, as the anteroposterior axis of the eye increases in length, this condition is corrected. Further increase in the anteroposterior axis could cause myopia but generally this is prevented by the simultaneous flattening of the lens as growth proceeds.
- A newborn baby perceives light and closes the eyes whenever there is a bright light. Eye movements are uncoordinated at first, and transient deviation of the eyes may be present. This condition may last several months but should stabilize by the fourth month. At the end of neonatal period, good fixation and following should be evident and accommodation (focusing) becomes better coordinated.
- The **lacrimal glands** do not function at birth → No tears when the child cries till the 3rd mouth

Senile Changes

- **Cornea**
  - **Arcus senilis** is a fatty infiltration of the cornea near its margin. This starts as two white crescents **superiorly & inferiorly**. Eventually the arcs fuse. The fatty degeneration occurs first in the superficial stroma and the Bowman's membrane.
  - Flat more vertically → Astigmatism against the rule
  - Descemet's membrane tends to form warts at the periphery
  - ↓ endothelium
  - ↓ Keratocytes

- **Sclera**
  - **↑ Thickening & Rigidity** especially at the orifices
  - The sclera becomes **yellowish** as the result of fatty infiltration.

- **Lens**
  - **Presbyopia (loss of accommodation)** results from hardening changes in the nucleus of the lens & changes in the ciliary body (↑ rigidity of ciliary body due to ↑ CT deposition → interfere with ciliary muscle contraction)
  - **Nuclear sclerosis**
  - **Senile cataract**

Congenital anomalies

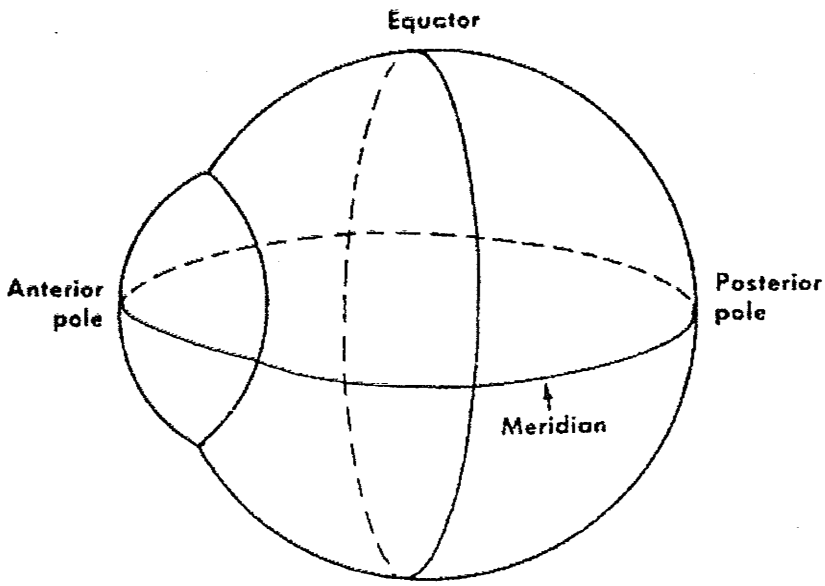
- **Congenital Cataract** the principal causes
  - **Chromosomal** abnormalities as Down syndrome. & **Genetic** abnormalities as Congenital galactosemia (cataract not present at birth, but develops as early as the 2nd week due to injury of the lens by the accumulated galactose)
  - **Infection**: e.g. If the mother is exposed to the **rubella** virus before the 7th **week** of pregnancy (a time when the lens is actively developing & before the development of the lens capsule) the child may have congenital cataract. If the mother contracts rubella after the 7th week, the lens is rarely affected.
  - **Malnutrition**: Many of the children with congenital cataract are of low birth weight and may have suffered from intrauterine malnutrition resulting front poor diet during the mother's pregnancy, maternal toxemia, or multiple pregnancy.

- **Coloboma**
  - A notched defect of a sector of the iris, ciliary body, retina, or choroid ⇒ caused by a failure closure of the optic fissure.
  - This condition may occur as an isolated lesion or in association with other malformations, especially cleft lip or palate.

- **Microphthalmos:**
  - Either grossly very small or appearing normal.
  - The affected side of the face is underdeveloped & the orbit is small.
  - It is due to ***arrested eye development*** before or shortly after the optic vesicle had formed in the 4th week
    - If before the optic fissure closes in 6th week → Larger eye + gross ocular defects
    - If in the 8th week → Small eye + minor ocular abnormalities (simple microphthalmos)

- **Anophthalmos:**
  - Eyelids formed + No eye ball
  - Two types
    - **Primary** (isolated) → due to failure of the **optic vesicle** to form.
    - **Secondary** → Due to supression of development of **forebrain**.

- **Cyclops:**
  - Both eyes are fused → Single median eye.
  - Caused by supression of **median cerebral structures** that develop from cranial part of neural plate.
  - Usually associated with severe **craniocerebral defects** → incompatible with life.


Equator
Anterior pole
Posterior pole
Meridian

The Eye

- The *anterior pole* of the eye is the center of curvature of the cornea.
- The *posterior pole* marks the center of the posterior curvature of the globe, and it is located slightly temporal to the optic nerve.
- The *geometric axis* is a line connecting these two poles.
- The *equator* encircles the eye midway between the two poles.

Globe measurements in adults:

- The *antero-posterior* diameter is about **24** mm.
- The *vertical* diameter is about **23** mm.
- The ***horizontal*** diameter is about **23.5** mm
- The *circumference* is between **69 - 81** mm.
- The *equator* is **16** mm posterior to the corneo-scleral limbus.
- The *posterior pole* is **32** mm behind the corneo-scleral limbus.
- The *ora serrata* is approximately **5.75 - 6.5** mm posterior to the termination of the Descemet's membrane and endothelium of the cornea (Schwalbe's line)

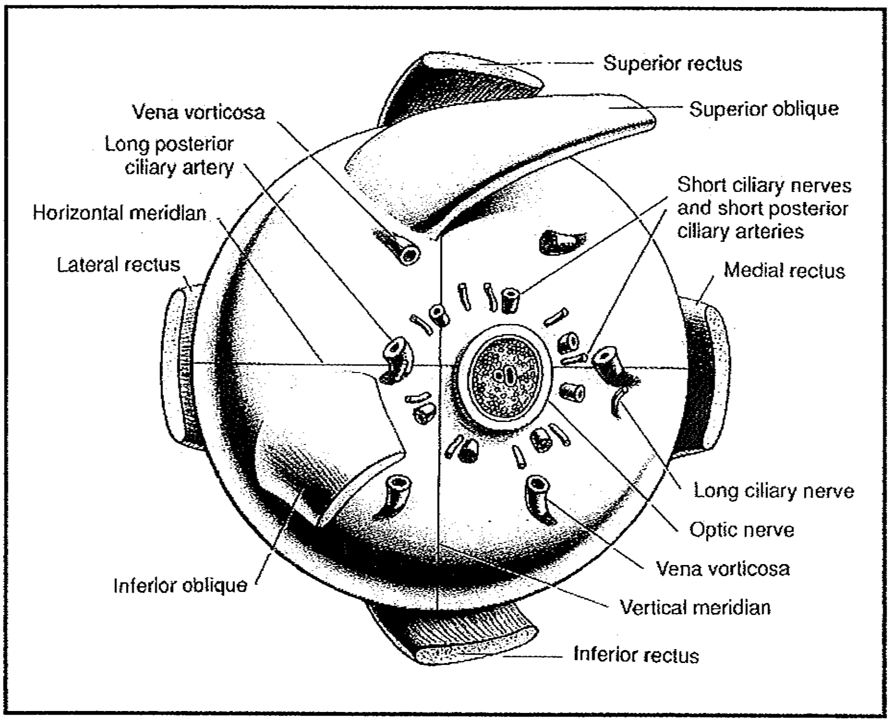
Volumes

1) Orbit ⇒ **30** cm^3
2) Globe ⇒ **7** cm^3
3) Vitreous ⇒ **3.9** cm^3
4) Aqueous ⇒ **124** mm^3

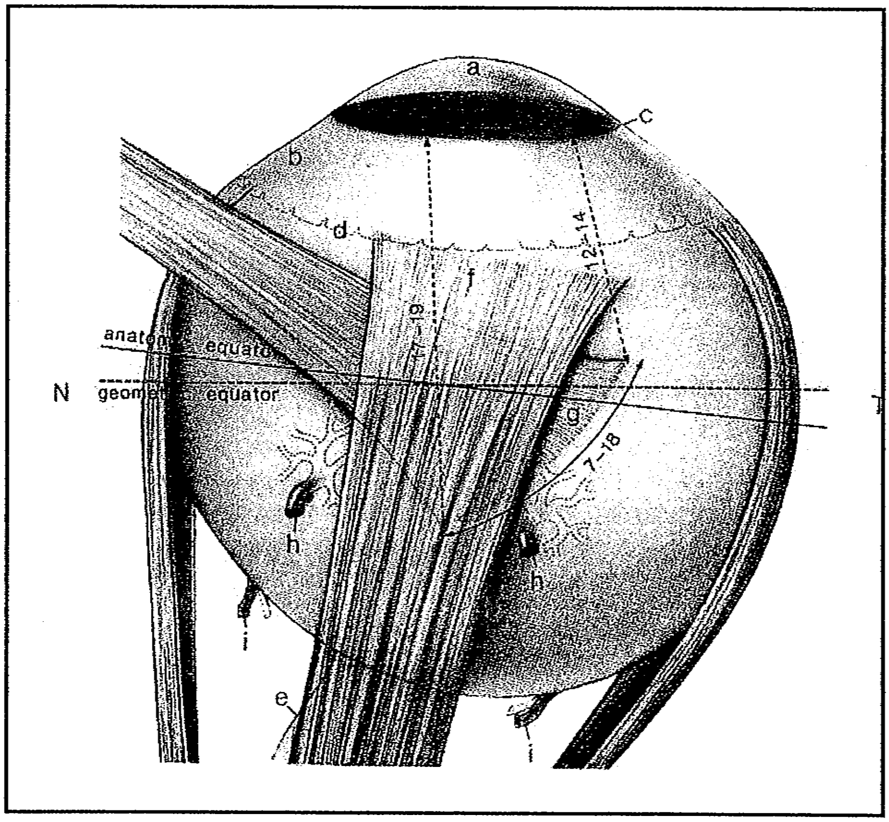
Volume of ORBIT	:	volume of GLOBE
30	**:**	**7**
4.5	**:**	**1**

Orbital measurements in adults:

- Depth = **40** mm
- Height of orbital opening = **35** mm
- Width of orbital opening = **40** mm
- Inter-orbital distance = **25** mm



Superior rectus
Superior oblique
Vena vorticosa
Long posterior ciliary artery
Horizontal meridian
Lateral rectus
Short ciliary nerves and short posterior ciliary arteries
Medial rectus
Long ciliary nerve
Optic nerve
Vena vorticosa
Vertical meridian
Inferior oblique
Inferior rectus



a
c
b
d
12–14
f
N
equator
g
7–18
h
h
e

The Globe

Outer coat

Sclera:

- Radius of curvature is about **13** mm.
- Constitutes the posterior $^{5}/_{6}$ of the globe.

Cornea:

- Radius of curvature is about **7.5** mm.
- Constitues the antersor $^{1}/_{6}$ of the globe.

Layers of Cornea end Sclera

I. Precorneal tear film

A. Oil Layer (from meibomian glands)
B. Aqueous layer (from lacrimal glands)
C. Mucoid layer (from goblet cells)

II. Cornea

A. Epithelium (anteriorly)
1. Surface cell layer
2. Wing cell layer
3. Basal cell layer (columnar cells)
4. Basement membrane

B. Stroma
1. Anterior condensation (Bowman zone)
2. Lamellar stroma (substantia propria)

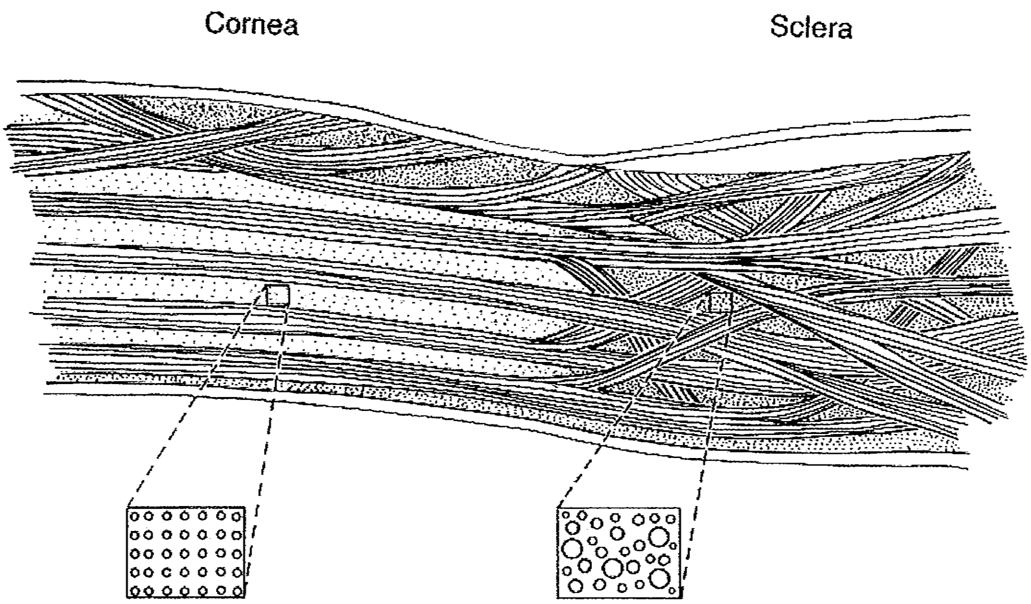
C. Mestothelium (endothelium) & Descemet's membrane (basement membrane)

III. Sclera

A. Episclera

B. Scleral stroma

C. Lamina fusca


Cornea
Sclera

Sclera (The hard)

- **Definition:** The opaque posterior 5/6 of the outer coat of the eye.

Gross:

- ***Thickness:***
  - Thickest (**1.0** mm) in the region surrounding the optic nerve.
  - Thinnest (**0.3** mm) immediately posterior to the insertions of the recti.
  - At the equator (**0.6** mm)
  - At the limbus (**0.8** mm)
- ***Radius of curvature:*** about **13** mm
- ***Colour:***
  - Outer surface:
    - → ***Opaque white*** (collagen fibers have **variable diameter**, **irregular arrangement** & **high water content**)
    - → ***Bluish*** in children & in scleral thinning (owing to the colour of the choroid)
    - → ***Yellowish*** in old (due to fat deposition)
  - Inner surface: ***Brown*** (due to adherent choroidal pigments)
- ***Anteriorly:*** it forms the "white" of the eye and is covered with **(1)** episclera **(2)** fascia bulbi (Tenon capsule) **(3)** conjunctiva.
- *Posteriorly*: the sclera is connected by loose, fine collagen fibers to the Tenon capsule
- *Openings*:

1) **Posterior scleral foramen**:
   - It is the canal through which the optic nerve & CRV leave the eye and through which the CRA enters the eye.
   - Site ⇒ **3 mm** medial to & just **1 mm** above the posterior pole.
   - Shape ⇒ *Cone-shaped* and Its diameter is :
     - → 1.5 - 2.0 mm on the inner surface of the sclera
     - → 3.0 - 3.5 mm on the outer surface.
   - Bridged by ***the lamina cribrosa***
     - ⇒ Definition: A *sieve like structure* that bridges the posterior Scleral foramen, forms *200-400 openings*, through which *bundles of RNF pass*.
     - ⇒ Formed of:
       - → fibrous tissue from the *sclera* → posteriorly
       - → elastic tissue of the *choroid & Bruch membrane*, and
       - → astroglia derived from the *septal system of the nerve* → anteriorly
     - ⇒ Arrangement:
       - → Antero-posterior section → 3-8 dense trabeculae pass out of the side wall of scleral canal
       - → Coronal section → 200-400 pores, the largest pores are arranged in an hour glass manner (superior & inferior) & have thin C.T wall & are vulnerable to glaucomatous damage.
       - → Scleral portion → formed of a *central vessel* (derived from circle of Zinn) surrounded by *collagenous & elastic fibers*
       - → Choroidal portion → formed only of *glial tissue*.

2) **Anterior scleral foramen:** bridged by the cornea. (elliptical anteriorly & circular internally)

3) **Vortex veins:** About *4mm posterior to the equator* of the eye in the regions between the recti muscles are the openings for the 4 vortex veins (the collecting channels for choroidal veins)

4) **Ciliary nerves & arteries:** In the area *surrounding the optic nerve*, the sclera is perforated by the 2 long and 6-10 short **ciliary nerves** and the 2 long and 10-20 short **posterior ciliary arteries.**

5) **Anterior ciliary arteries:** pierce the sclera at sites sometimes marked with a dot of uveal pigment. about *4 mm posterior to the corneoscleral limbus and just anterior to the insertions of the recti muscles*

Occasionally a **loop of a long ciliary nerve** surfaces on the sclera & returns to the ciliary body. Uveal melanin marks the loop as a small pigmented dot *2-4 mm from the corneoscleral limbus*.

- **Structure:** three layers (from without inwards):

(1) Episclera:

- **Moderately dense, vascular CT** that merges with the scleral stroma and sends CT bundles into the Tenon capsule.
- The anterior portion of the episclera has a ***rich blood supply*** that may become markedly congested in inflammation.
- Behind the equator the episclera and the fascia bulbi are ***attenuated***; this accounts for the relative avascularity of the posterior sclera.

(2) Scleral stroma:

- **bundles of typical collagen fibers** (no elastic fibers but collagen fibers have **viscoelastic** property)
  - Diameter from **10 - 16** μm.
  - Length from **30 – 140** μm.
  - Arrangement
    - ***Parallel*** to the corneoscleral limbus = coronally circular (basketlike weave)
    - ***Meridional***, In the region of the insertion of the extraocular muscles. apparently in response to mechanical stress induced by traction of the ocular muscles & IOP.
  - The sclera is **white** because the collagen fibers of the stroma have:
    - ***Variable diameter***
    - ***Irregular arrangement***
    - ***High water content*** : When the water content of the sclera (usually between 65% & 70%) is reduced to less than 40% or increased to more than 80%, the sclera becomes transparent.
    - ***No blood vessels***
- Cells
  - **Fibroblasts** (irregular nuclei & dont make intimal contact)
  - **Pigment cells** (derived from lamina fusca)

(3) Lamina fusca:

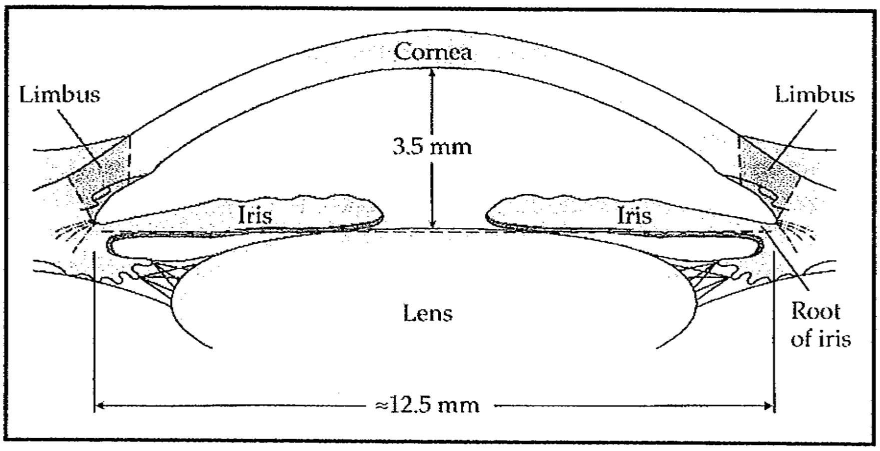
- Formed mainly of ***elastic*** fibers & fine collagen fibers form delicate connections between the sclera & the choroid.
- ***Brown color*** (provided by many melanocytes from the choroid)

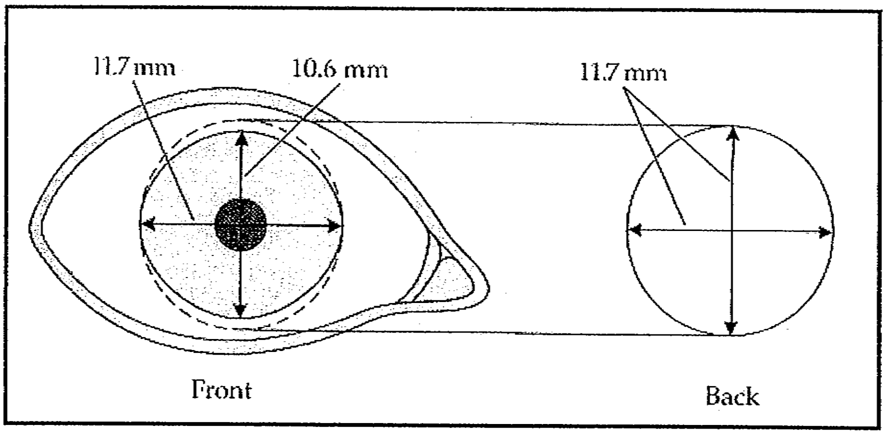
☐ **Blood supply:** Sclera is nearly avascular getting its blood supply from the ***episeleral*** and ***choroidal*** vascular networks.

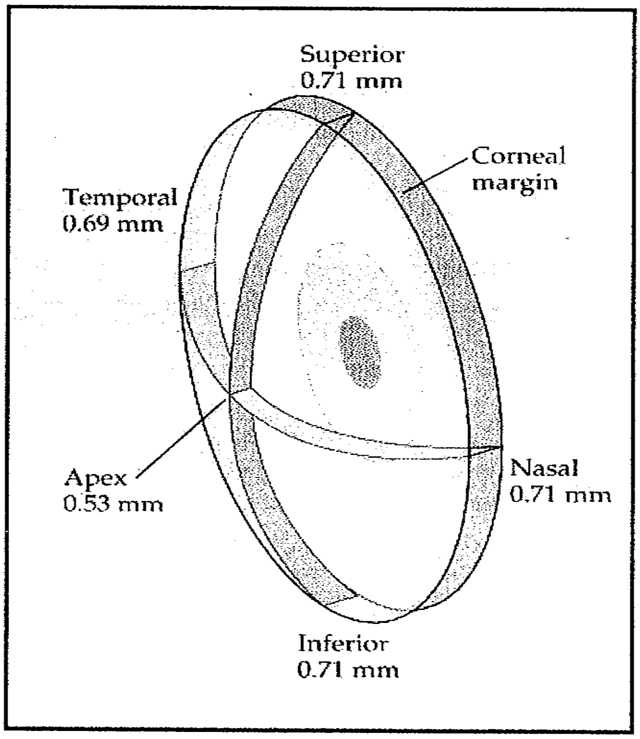
From inside : Choroidal vascular network
From outside :
- *Anterior to the insertions of the recti muscles*, the anterior ciliary arteries form a **dense episcleral plexus.** These vessels become congested in ciliary injection.
- *Posterior to the recti muscles*.Small branches of the **long & short posterior ciliary arteries**

☐ **Nerve supply:** Ciliary nerves perforate the sclera around the optic nerve
- ***6-10 short ciliary nerves*** → supply The posterior sclera
- *2* ***Long ciliary nerves*** → supply The anterior sclera

- Generous innervation makes inflammation of the sclera extremely painful
- The pain may ↑ with ocular movement because of attachment of EOM to sclera


Cornea
Limbus
Limbus
3.5 mm
Iris
Iris
Lens
Root of iris
≈12.5 mm


11.7 mm
10.6 mm
11.7 mm
Front
Back


Superior
0.71 mm
Corneal margin
Temporal
0.69 mm
Apex
0.53 mm
Nasal
0.71 mm
Inferior
0.71 mm

Cornea

- **Definition:** The transparent anterior 1/6 of the outer coat of the eye.

Gross:

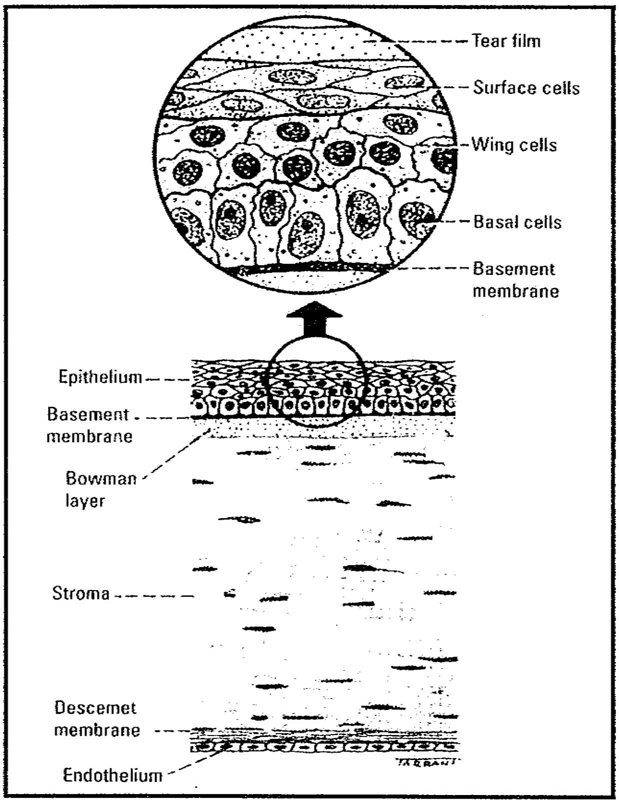
- *Margins*:
  - Its *anterior peripheral margin* merges with the sclera and is covered with conjunctiva.
  - Its *internal margin* terminates at the trabecular meshwork.

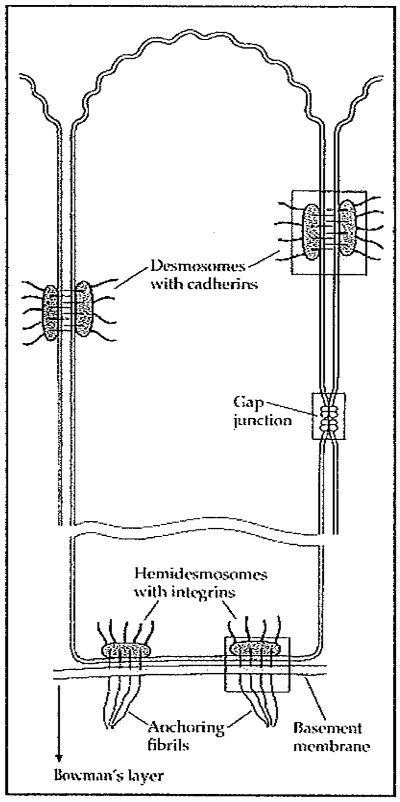
- *Measurements*:
  - **Diameter:**
    - Anteriorly: elliptical
      - vertically about **10.6** mm (due to greater conjunctival & scleral overlap above & below)
      - horizontally about **11.7** mm .
    - Internally: the cornea is circular with a diameter of **11.7** mm.
  - **Thickness:**
    - The central optical portion is **0.52** mm.
    - The peripheral portion is **1.0** mm.
  - **The radius of curvature:** (Variations in the radius of curvature in different meridians cause astigmatism)
    - of the convex anterior surface is **7.8** mm.
    - of the concave posterior surface is **6.5** mm.
  - **Refractive index**: The cornea (RI = **1.376**) separates
    - air (RI = **1.00**) and
    - aqueous humor (RI = **1.336**)
  - **Corneal growth:** is complete in humans at about **6** years of age.

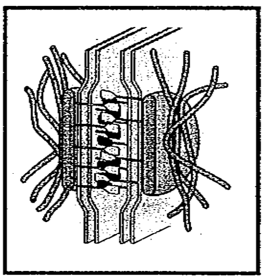
- *Transparency*
  - Anatomical factors
    - Epithelium is non-keratinized
    - Stromal lamellae are regularly arranged
    - Cornea is avascular
    - Nerves have no myelin.
  - Physical factors
    - RI of the fibers & matrix is the same
  - Physiological factors
    - Detergescence

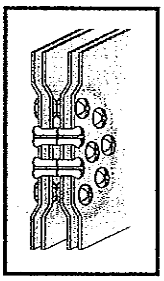
> **Causes of Detergescence**
>
> **1- From outside**
> Tear evaporation → Hypertonic tear → Draw water from the cronea
>
> **2- From inside**
> Normal IOP ⇒ If ↑ > 50 mmHg → Edema
>
> **3- Inbetween**
> - Epithelial & Endothelial integrity
> - Na^+ K^+ ATPase pump → activity

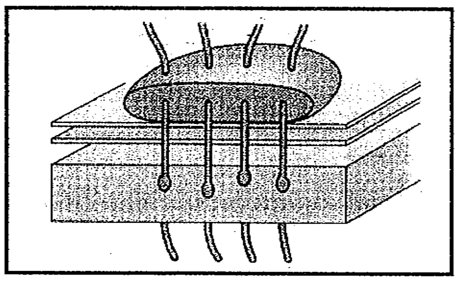
- ***Lustur*** *(means that we can see the source of light on the surface = window reflex)*
  - Smooth epithelial surface
  - Tear film
  - Mucous fills the epithelial irregularities.

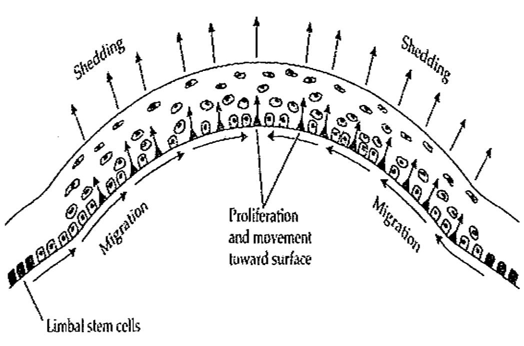

Tear film
Surface cells
Wing cells
Basal cells
Basement membrane
Epithelium
Basement membrane
Bowman layer
Stroma
Descemet membrane
Endothelium

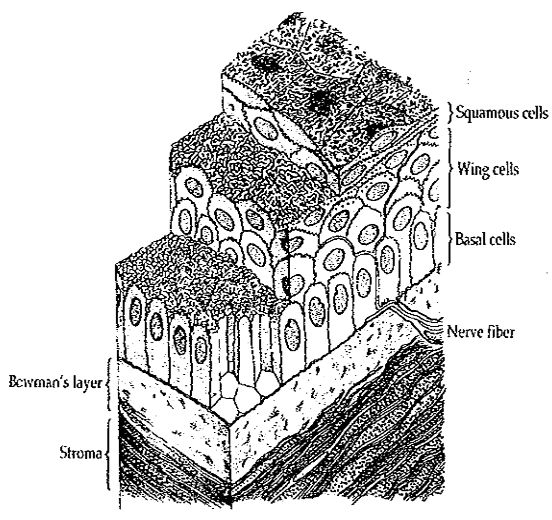

Desmosomes with cadherins
Gap junction
Hemidesmosomes with integrins
Anchoring fibrils
Basement membrane
Bowman's layer








Shedding
Shedding
Migration
Migration
Proliferation and movement toward surface
Limbal stem cells


Squamous cells
Wing cells
Basal cells
Nerve fiber
Bowman's layer
Stroma

Structure: 5 layers (from anterior to posterior)

- **The Epithelium:** (50 - 90 μm)
  - **Type** → **Stratified squamous epithelium** (5-6 cell layers at the center, ↑ to 10 at the limbus)
  - **Regeneration:** occurs at the limbus, with migration of epithelial cells to cover any defect.
  - **Turn over:** epithelial cells form in the deepest layer, become progressively flatter, and are shed from the superficial layer 7 days later.
  - **Structure**

⇨ *Cells*

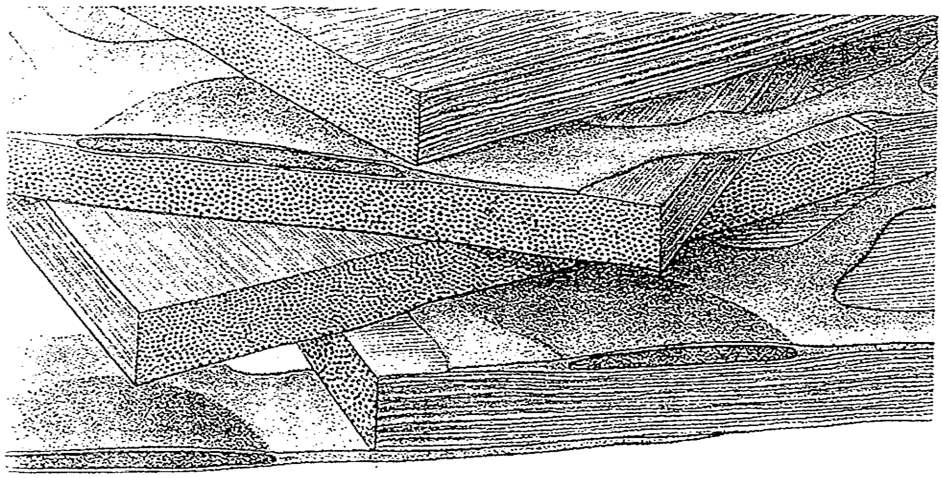
1) **Surface cell layer** (outer 2-3 cell layers)
   - ***Flat***, with many ***microvilli***. & ***horizontal nuclei***
   - Joined to each other with ***desmosomes*** & lateral interdigitations that prevent aqueous solutions (such as tears) from penetrating the cornea.
   - As superficial cells age, they lose their interdigitations and disintegrate or are swept away by the eyelids during blinking
2) **Wing cell layer** = Umbrella cells (middle 3-4 cell layers)
   - ***Polyhedral*** with a convex anterior surface, parallel with the surface of the cornea, and a concave posterior surface.
   - Deep cells have ***round nuclei*** that become successively ***flatter*** as the cells approach the surface of the cornea.
   - Joined together from base to apex by ***desmosomes*** & ***zonula occludens***
3) **Basal cell layer** (inner single layer)
   - ***Tall and columnar*** cells that often show ***mitosis***.
   - Their interdigitating lateral cell borders are joined by ***desmosomes***.
   - They are joined to the basement membrane by ***hemidesmosomes***.

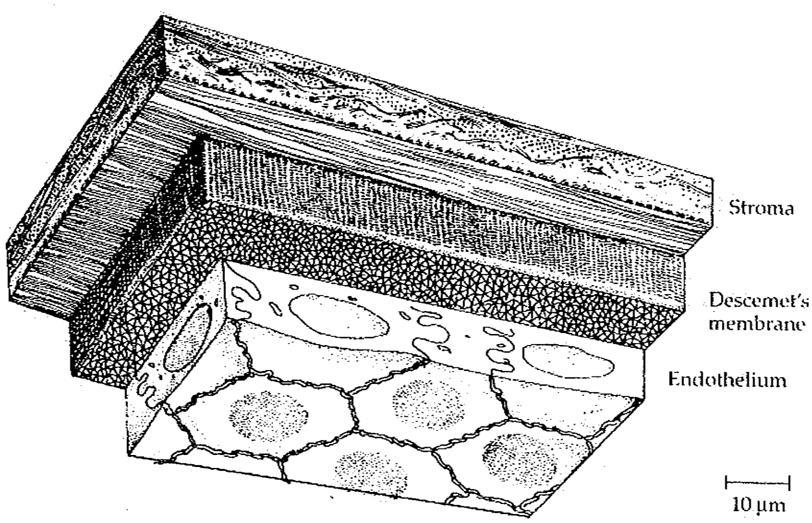
> ***Few leucocytes*** are present between basal cells at corneal periphery → ↑ in inflammation

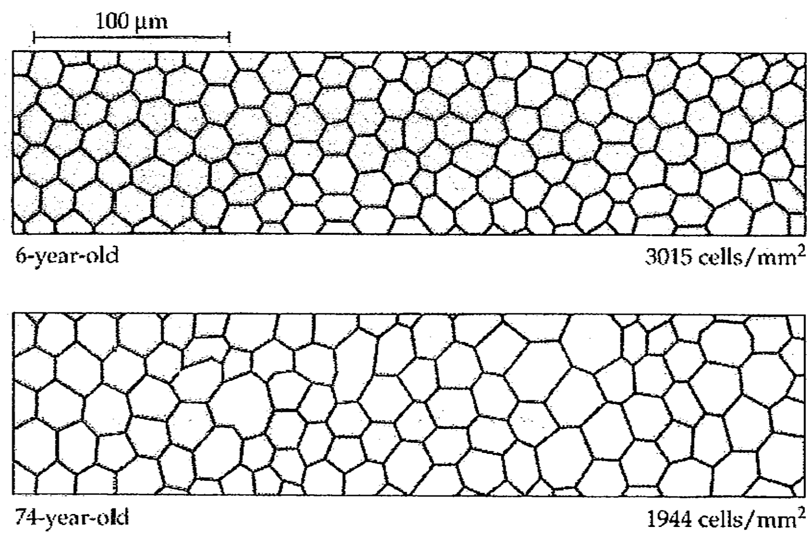
⇨ ***Basement membrane***
- PAS positive
- Firmly attached to the underlying Bowman zone by ***irregular filaments***, (After injury, these attachments may take as long as 6 weeks to be reestablished)
- Secreted by basal cells & formed of superficial lamina lucida & deep lamina densa

⇨ ***Lymph spaces*** → minute spaces in between basal cells & disappear gradually towards the surface. May be distended pathologically (e.g. glaucoma)

⇨ ***Cell junctions*** *occuring in corneal epithelium*
- **Zonula occludens** (tight junctions)
  - → Between wing cells
  - → Junction encircle the cell & form a seal which prevent small molecules to pass
- **Zonula adherence** (desmosomes)
  - → Between basal cells
  - → Structure → see diagram
- **Hemidesmosomes**
  - → Between basal cells & basement membrane
  - → Structure → half desmosome




Stroma
Descemet's membrane
Endothelium
10 µm


100 µm
6-year-old
3015 cells/mm^2
74-year-old
1944 cells/mm^2

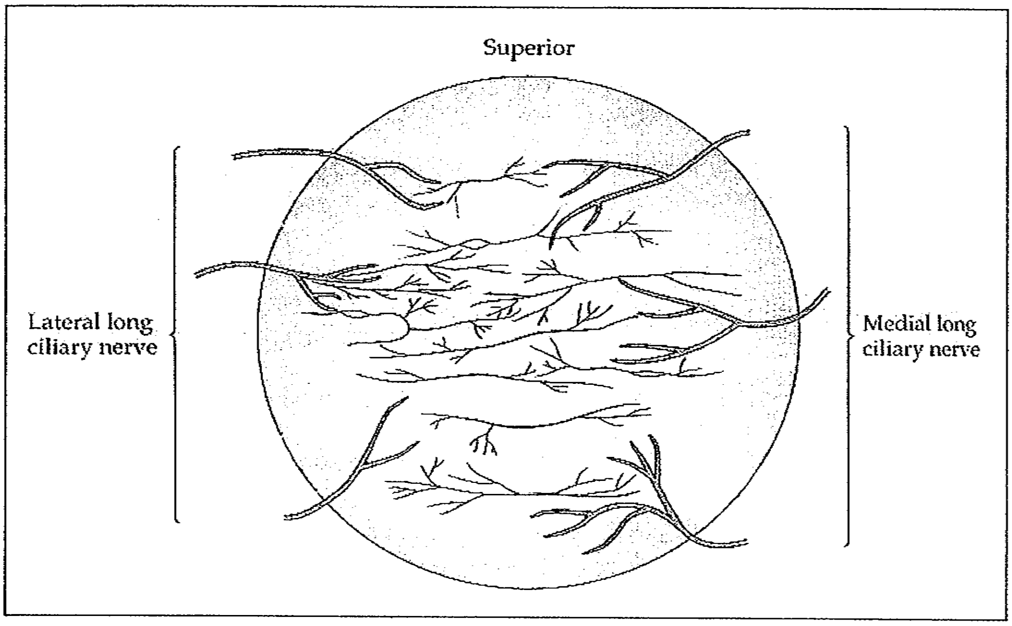
- **Bowman's membrane:** (12 μm)
  - Structureless, acelular hyaline superficial stroma
  - Made up of randomly oriented ***collagen fibers*** (Modified superficial stroma)
  - ***Resistant*** to trauma & infection
  - ***Doesn't regenerate*** after damage→ irregular astigmatism.
  - Contains perforations for passage of superficial epithelial plexus of nerves
  - Terminates abrubtly at the limbus.

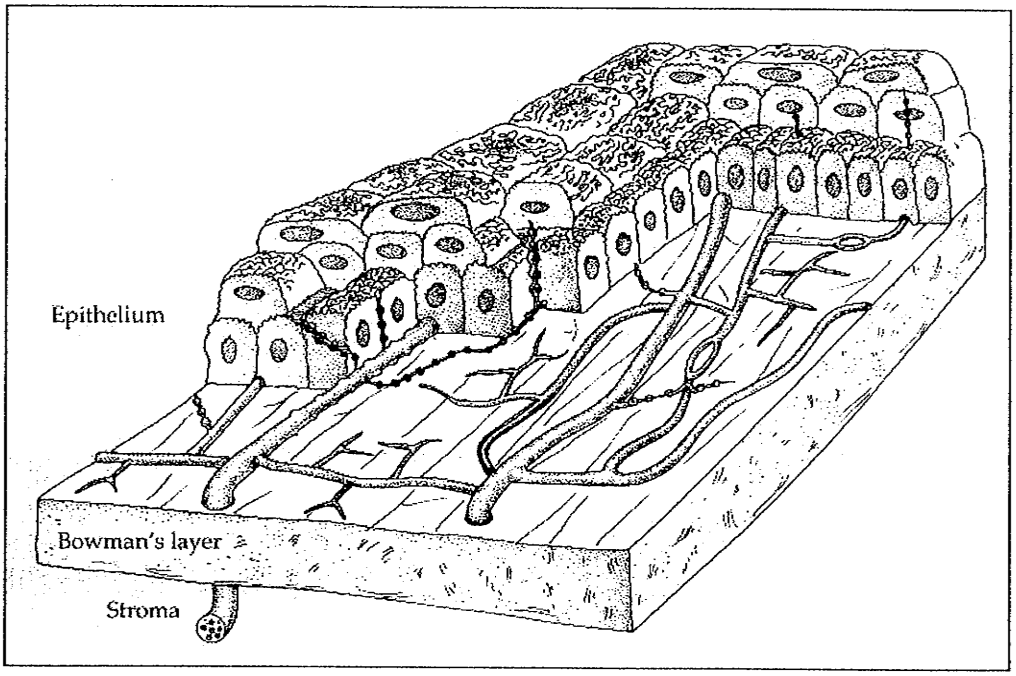
- **Lamellar stroma:** (500 μm = 90% of corneal thickness) Composed of
  - Lamellae of ***Collagen fibrils*** (arranged in a regular lattice)
    1. Uniform diameter and regular spacing
    2. Extend the entire width of the cornea. (from limbus to limbus)
    3. Thickness:
       a. In the *posterior cornea*, the lamellae are of almost equal thickness
       b. In the *anterior cornea*, they become more irregular
    4. Fibers within a lamella are parallel but at a right angle to fibers in the adjacent lamellae.
  - They are enmeshed in ***glycosaminoglycans***. *(chondrotin sulphate & keratan sulphate)*
  - *Cells:*
    1. ***Keratocytes*** (corneal corpuscles) ⇒ fixed, and flat cells, with flat nuclei & long cytoplasmic processes which function as fibroblasts do in other tissues.
    2. Few ***wandering cells*** (leukocytes and macrophages). → ↑ in inflammation

- **Descemet membrane:** (12 μm in adults & 5 μm in childs)
  - A loosely attached PAS-positive structurelss, hyaline glassy membrane .
  - Made up of *type 4* ***collagen fibers*** (arranged in a hexagonal pattern)
  - ***Very resistant*** to infection & trauma
  - ***Regenerates*** readily after injury (but not its endothelial cells in humans) and may form glassy membranes that extend into the anterior chamber.
  - Terminates abruptly at the periphery of the cornea to form the ***line of Schwalbe***, the anterior border of the trabecular meshwork.
  - It is the basement membrane of endothelial cells.
  - In corneal aging it shows peripheral excrescence called *Hassal Henle bodies* (due to focal overproduction of basal lamina)

- **Mesothelium:**
  - A single layer of ***hexagonal*** endothelial cells contain ***large oval nuclei*** and are rich in ***intracellular organelles***.
  - Cell apices are in direct contact with the aqueous humor and have ***occasional microvilli***.
  - The cells are tightly bound together with ***desmosomes*** & ***tight junctions***.
  - Responsible for the ***deturgescence*** of the corneal stroma.
  - ***Does not regenerate*** (but compansate by pleomorphism & polymegathism)

> At the corneal periphery, the **Bowman** membrane and the **Descemet** membrane stop abruptly.
> A line connecting these terminations constitutes the anterior margin of the corneoscleral limbus.


Superior
Lateral long ciliary nerve
Medial long ciliary nerve


Epithelium
Bowman's layer
Stroma

Blood supply:

- **Central** cornea is avascular (nutrition from **Aqueous** & **Tear film** → 90% of O_2)
- **Corneoscleral** limbus is supplied by ***anterior conjunctival branches*** *of the anterior ciliary arteries*.

Nerve supply:

Corneal nerves

- **Trigeminal n.**
  - → **Ophthalmic n.**
    - → **Nasociliary n.**
      - → **Long ciliary n.**
        - → **Corneal nerves.**

- **Distribution:**

  ⇨ **Pericorneal nerve plexus**

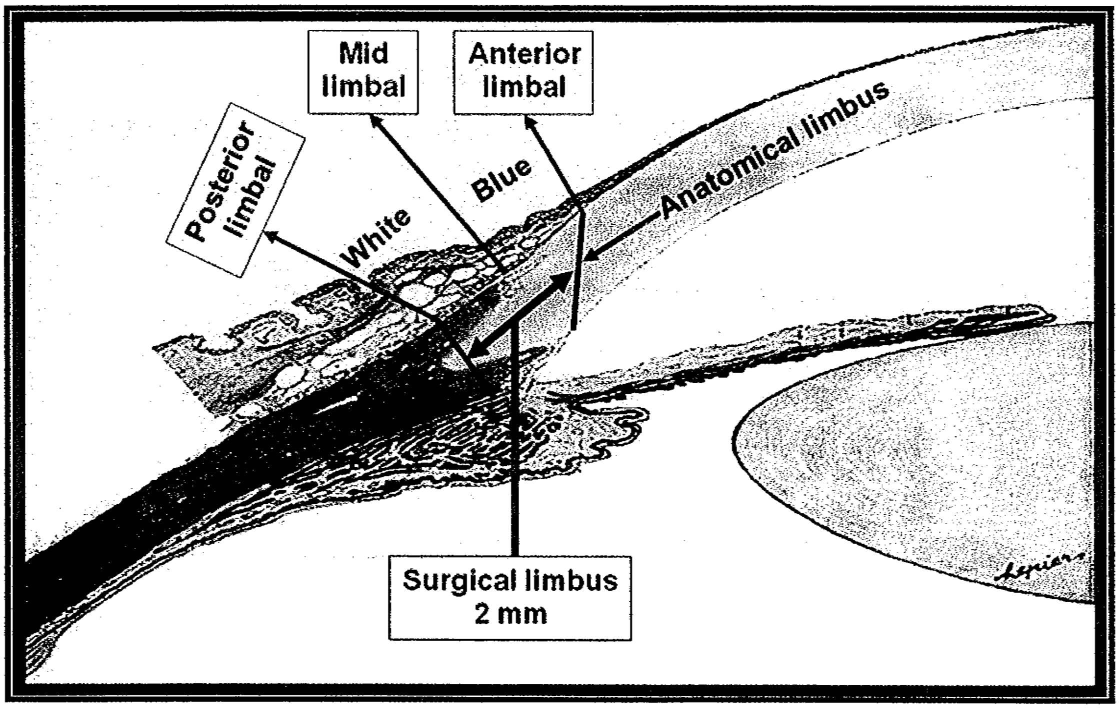
  - Formed by
    1) Long ciliary nerves (which enter the sclera from the suprachoroidal space)
    2) Conjunctival nerves
  - It sends 60-80 myelinated nerve fibers → radially enter the mid-stromal cornea

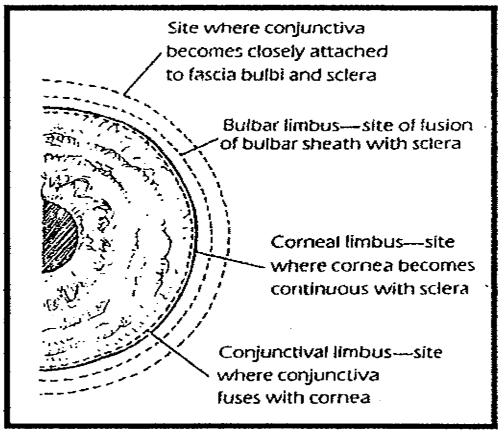
  ⇨ **Corneal nerves**

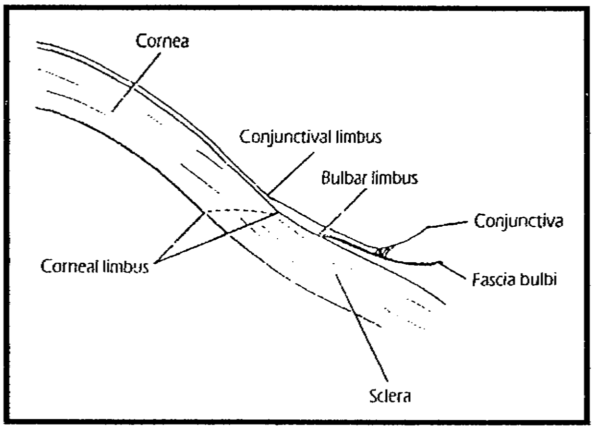
  travel for 2-3 mm → loose their myelin sheath & divide in 2 groups

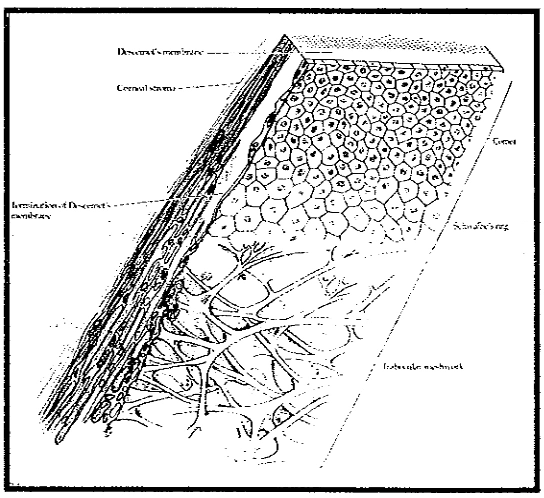
  - ***Anterior group*** ⇒ Form a plexus beneath Bowmans → send branches to form
    1) Subepithelilal plexus
    2) Intraepithelial plexus
  - ***Posterior group*** ⇒ Supply posterior part of the stroma.

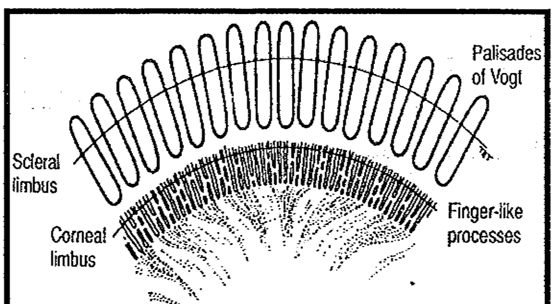
- **Charachters:**
  - ***Only Sensory*** *(Cold & Pain)*
  - *Non-myelinated (They gain their myelin sheath at the corneoscleral junction)*
  - ***No specialized nerve endings***
  - Most are ***concentrated in the anterior stroma***
  - Descemet membrane and the endothelium are not innervated.


Mid limbal
Anterior limbal
Posterior limbal
Blue
White
Anatomical limbus
Surgical limbus
2 mm


Site where conjunctiva becomes closely attached to fascia bulbi and sclera
Bulbar limbus—site of fusion of bulbar sheath with sclera
Corneal limbus—site where cornea becomes continuous with sclera
Conjunctival limbus—site where conjunctiva fuses with cornea


Cornea
Conjunctival limbus
Bulbar limbus
Conjunctiva
Corneal limbus
Fascia bulbi
Sclera




Palisades of Vogt
Scleral limbus
Finger-like processes
Corneal limbus

M.Omar

Corneo Scleral Limbus

1mm posterior to the conjunctival limbus

Definition:

- Transitional zone 1-2 mm wide between the transparent cornea & the opaque sclera.
- Covered by Conjunctiva & Contains the trabecluar meshwork with its canal of schlemm

Its internal edge Anterior limbal border **Corneal limbus** Corresponds to a line joining the termination of Bowman's & Descemet's membranes	Mid-limbal dividing line Overlies Schwalbe's line (The peripheral termination of DM)	Its external edge Posterior limbal border **Scleral limbus** Corresponds to a line perpendicular to the surface passing through the scleral spur or the Iris root

Anterior limbal region	Posterior limbal region
Blue zone Extends from ALB to MLL (1mm) Overlies **clear cornea**	**White** zone Extends from PLB to MLL (1mm) Overlies **Trabecular meshwork**

Surgical limbus: 2mm wide zone from ALB to PLB

Gross anatomy:

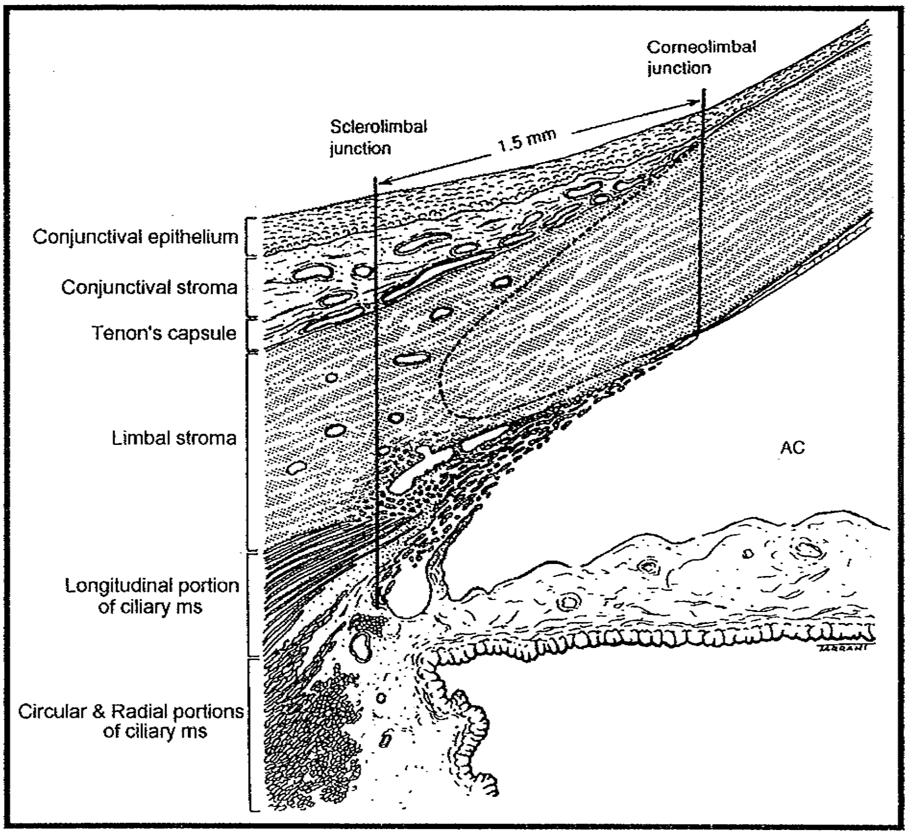
- Colour → Pigmented in dark races & may contain gross striations
- Well vascularized and contains myelinated nerve fibers.
- Parts:
  - Deep → Contains Trabecular meshwork & schlemm's canal
  - Mid-limbus → Contains transitional corneoscleral tissue + intrascleral venous plexus
  - Superficial → Episclera + tenon's capsule + conjunctival stroma + limbal epithelium.

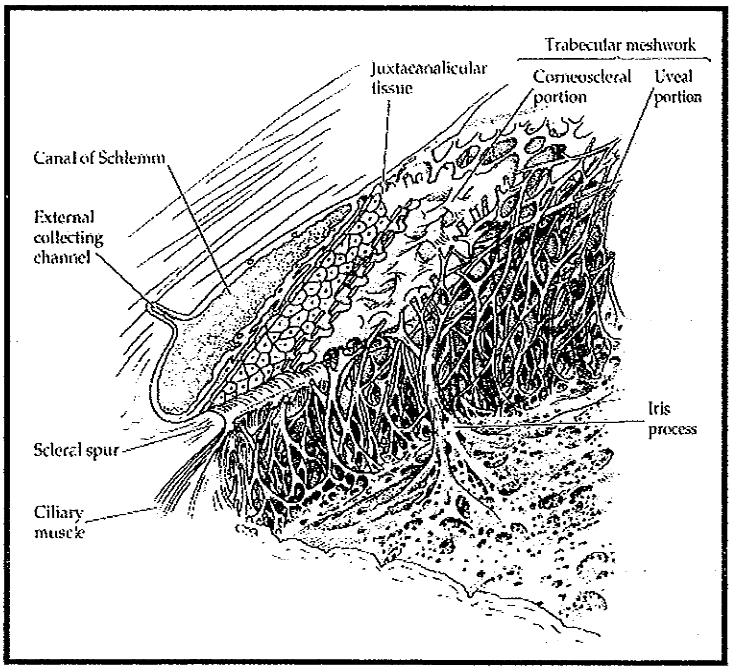
Structure:

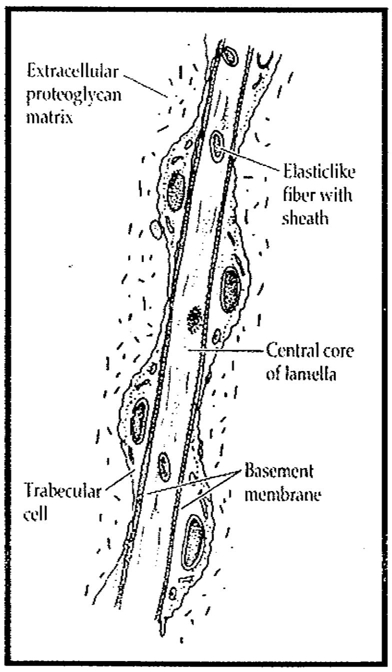
- ***Stratified squamous non keratinized epithelium***
  - Epithelial cells (5-7 cell layers)
    (1) Deep cylindrical (large stained nuclei & minimal cytoplasm & pigment granules)
    (2) Middle plygonal cell layers with no desmosopmes (unlike cornea)
    (3) Superficial flat cells (oval nuclei parallel to the surface)
  - BM: wavy with numerous folds (resemble dermal papillae) run radially into the cornea → known as *palisades of Vogt* *(epithelial cells thrown into folds by subepithelial CT at the limbus)*
- ***Stroma***: the regular lamellae of the cornea becomes the oblique & circular lamellae of the sclera

Changes that occur at the corneo-scleral limbus:

- ***Epithelium*** → loses its regular structure & becomes continuous with the conjunctival epithelium that contains goblet cells and lymphtatic channels.
- ***Bowman's membrane*** → ends abruptly in a loose arrangement of collagen fibers, filaments, and amorphous material.
- ***Corneal lamellar stroma*** → loses the regularity & the collagen fibrils vary in Diameter
- ***Descemet's membrane*** → Ends as Schwalbe's line (marking the begining of the TM)
- Corneal ***Endothelium*** → continues as endothelium that covers each of the bands of the TM.


Corneolimbal junction
Sclerolimbal junction
1.5 mm
Conjunctival epithelium
Conjunctival stroma
Tenon's capsule
Limbal stroma
AC
Longitudinal portion of ciliary ms
Circular & Radial portions of ciliary ms


Trabecular meshwork
Juxtacanalicular tissue
Corneoscleral portion
Uveal portion
Canal of Schlemm
External collecting channel
Iris process
Scleral spur
Ciliary muscle


Extracellular proteoglycan matrix
Elasticlike fiber with sheath
Central core of lamella
Basement membrane
Trabecular cell

Trabecular Meshwork

- **Definition:** Sieve-like structure at the angle of the anterior chamber, through which 90% of aqueous humour leaves the eye by filtring into the canal of Schlemm.

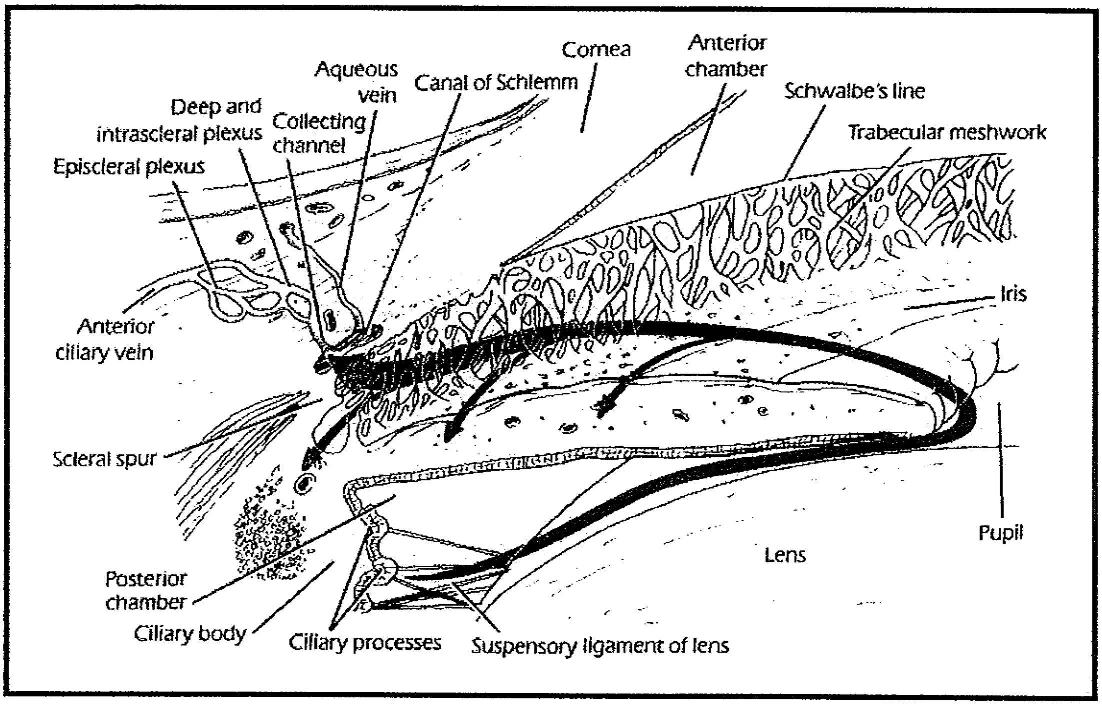
- **Parts:**
  - *Uveal meshwork*: (Inner most part)
    - Faces the Anterior chamber
    - Wide intertrabecular spaces → Little resistance to the passage of aqueous.
    - **Extension**
      - Inner leave → from Schwalbe's line to iris root
      - Outer leave → from Schwalbe's line to scleral spur
  - *Corneoscleral meshwork*: (Middle part)
    - Between the canal of Schlemm & anterior chamber.
    - Smaller intertrabecular spaces.
    - **Extension** (Triangular in meridional section)
      - Apex (Anterior) → attached to Schwalbe's line.
      - Base (posterior) → attached to the scleral spur & ciliary body.
      - Inner surface → faces anterior chamber
      - Outer surface → Anterior ⅓ → sclera & posterior ⅔ → endothelial meshwork
  - *Endothelial (juxtacanalicular) meshwork*: (Outer most part)
    - Lines Inner wall of Schlemm's canal. (linking its endothlium to the corneoscleral meshwork)
    - Smallest intertrabecular spaces → maximum normal resistance to aqueous outflow

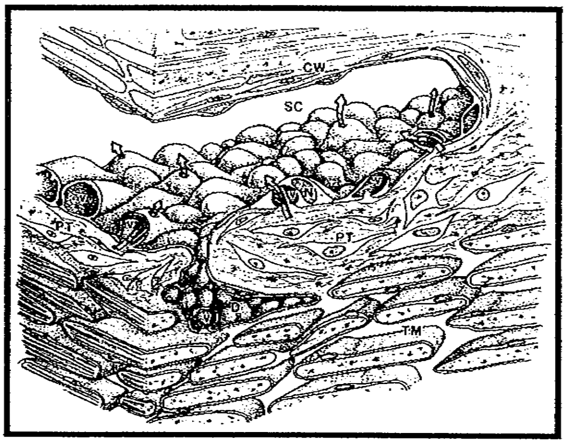
- **Structure:**
  - ⇨ A number of superimposed ***fibrocellular cords*** that enclose oval, circular, or rhomboidal ***spaces.***
    - Number of layers of cords
      - *Near the scleral spur* the meshwork contains approximately **12 layers** of cords
      - *Near the line of Schwalbe* there are only **2-3 layers.**
    - Structure of cord
      - ***Collagen & elastic core,***
      - surrounded by a thin ***matrix containing fibrils***, *(basement membrane)*
      - covered by ***epithelium*** *(flat cells with flat nuclei).*

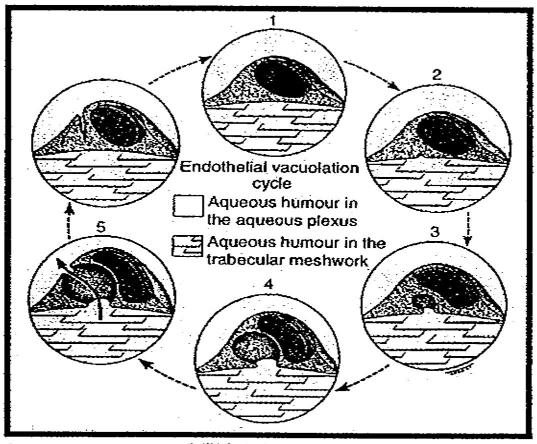
> N.B. Fibers of the longitudinal portion of the ciliary muscle terminate in the region adjacent to the canal of Schlemm.

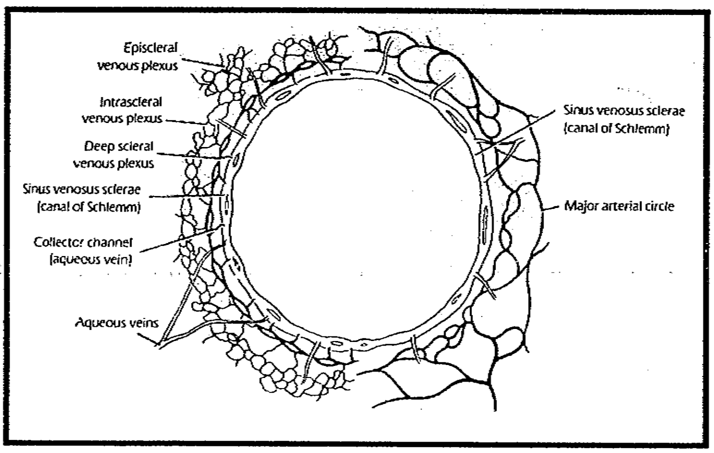
- **Innervation:**

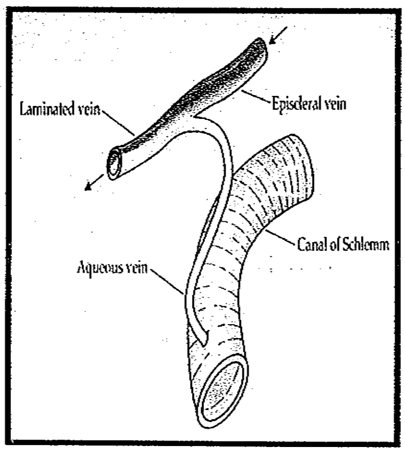
The trabecular meshwork is innervated by a plexus of delicate axons that terminate without specialized endings *within the endothelium* of the canal of Schlemm. The nerves originate from both the ***trigeminal nerve*** and the ***sympathetic*** nervous system.


Cornea
Anterior chamber
Aqueous vein
Canal of Schlemm
Schwalbe's line
Deep and intrascleral plexus
Collecting channel
Trabecular meshwork
Episcleral plexus
Iris
Anterior ciliary vein
Scleral spur
Pupil
Lens
Posterior chamber
Ciliary body
Ciliary processes
Suspensory ligament of lens


CW
SC
PT
PT
TM


1
2
3
4
5
Endothelial vacuolation cycle
Aqueous humour in the aqueous plexus
Aqueous humour in the trabecular meshwork


Episcleral venous plexus
Intrascleral venous plexus
Deep scleral venous plexus
Sinus venosus sclerae (canal of Schlemm)
Collector channel (aqueous vein)
Aqueous veins
Sinus venosus sclerae (canal of Schlemm)
Major arterial circle


Laminated vein
Episcleral vein
Canal of Schlemm
Aqueous vein

Canal of Schlemm

(Sinus Venous Sclerae)

- **Definition:** An oval channel that encircles the entire circumference of the ant. chamber.

- **Gross:**
  - Site: At the ***corneoscleral limbus*** (in the posterior limbal region) within the ***internal scleral sulcus.***
  - Shape: Flattened oval or triangular (wider posteriorly)
  - Thickness: **0.25 – 0.3** mm
  - Number: Mostly ***single***, but may be 2 or more & it divides into branches which reunite again.

- **Structure:** It is lined with a ***single layer of endothelium***
  - Inner wall (adjacent to TM) → Spindle shaped cells with big nuclei projecting inwards
    - → Contain ⇒ *Giant vacuoles* (invaginated basal plasma membrane) + pinocytic vesicles + ribosomes
    - → Have surface microvilli
    - → Joined together by ***Zonula occludens***.
    - → Rest on an incomplete basement membrane.
  - Outer wall → cells (1) larger (2) flatter (3) smoother (4) rare giant vacuoles.

- **Relations:**
  - Inner wall → **Trabecular meshwork**
  - Outer wall → **Sclera**
  - The **scleral spur** bounds the canal posteriorly & overlaps it somewhat to the inner side.

- **Contents:**
  - Aqueous humour
  - Blood (only in ***gonioscopy*** due to blood influx due to pressure on the limbus by goinolens but not in ***cut section***)

- **Communications & Function:** → 90 % of aqueous drainage.
  - **Inner wall** communicates with the ***anterior chamber*** through
    - Trabecular meshwork.
    - Canals of Sondermann (endothelium lined canals extend from Schlemm's canal into the trabecular meshwork)

Mechanisms responsible for aqueous drainage throught endothelium of Schlemm's canal
(1) Transcellular (via giant cytoplasmic vacuoles) **(2)** Intercellular **(3)** Pinocytosis (active transport)

  - **Outer wall** communicates with the ***venous system*** through

Collector channels (25-35) anastomose to form **Deep scleral venous plexus**
↓
Intra-scleral venous plexus
↓
Episcleral venous plexus & Subconjunctival venous plexus

Aqueous veins (up to 8)
Transmit > 50% of aqueous
collector channels that bypass these plexuses and continue through the sclera.
They may be seen as subconjunctival minute vessels, which contain clear aqueous humor
→ (to Episcleral & Subconjunctival venous plexus)

Middle Coat

- The ***choroid*** is a vascular layer that provides the blood supply to the retinal pigment epithelium and the outer half of the sensory retina adjacent to it.
- The ***ciliary body***
    - Secretes aqueous humor.
    - Contains the smooth muscle responsible for changing the lens shape in accommodation.
- The ***iris*** surrounds the ***pupil*** a central opening that controls the amount of light entering the eye.

Layers of Uvea and Bruch Membrane

Uvea

- *Choroid*
    1. Lamina fusca (suprachoroid)
    2. Layer of large veins (of Haller)
    3. Layer of smaller veins (of Sattler)
    4. Choriocapillaris (blood supply of the outer retina)
- *Ciliary body*
    - Uveal portion
        - Lamina fusca (supraciliaris)
        - Vessel layer
        - Ciliary muscle
            1) Longitudinal
            2) Radial
            3) Circular
    - Epithelial portion
        - Pigmented epithelium
        - Nonpigmented epitlielium
- *Iris*
    - Anterior border layer (fibroblasts and melanocytes, absent in pupillary zone)
    - Stroma (connective tissue, blood vessels. sphincter pupillae muscle (N III)
    - Epithelium
        - Anterior (myoepithelium: dilator pupillae muscle (sympathetic)
        - Posterior pigmented layer

Bruch membrane (lamina basalis choroideae)

A. Basement membrane of choriocapillaris endothelium..
B. Outer collagen layer.
C. Elastic layer.
D. Inner cuticular layer. (Inner collagen layer)
E. Basement membrane of pigment epithelium.

The Choroid

Definition:

- A vascular sheet that forms the most posterior part of the middle coat of the eye.
- Extends from the ***optic nerve*** posteriorly to the ***ciliary body*** anteriorly.

Function:

- Provides the blood supply for the RPE & the outer one half of the sensory retina
- Absorbs excess light that penetrates the retina throught its pigment cells → thus prevents light reflection

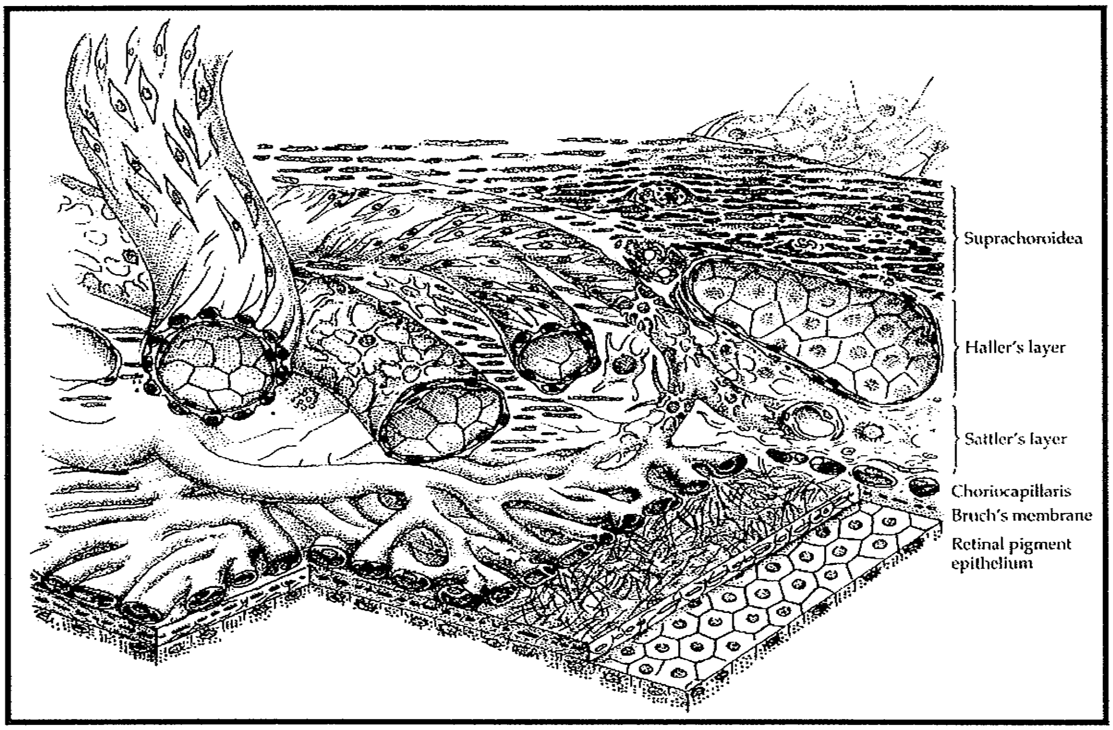
Gross:

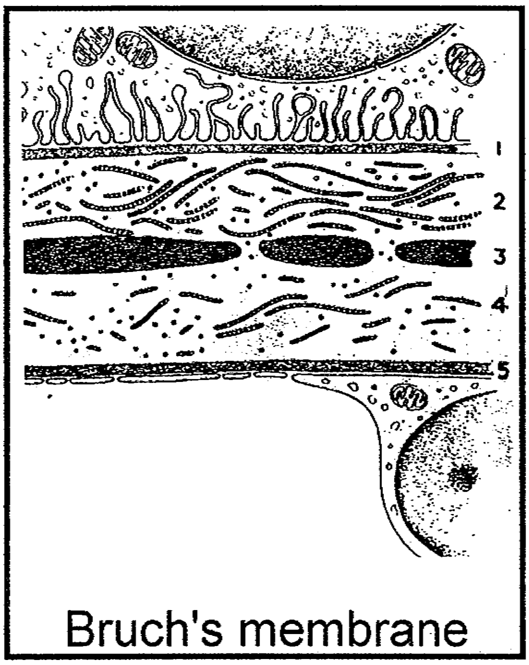
- ***Extends***
  - From the **optic nerve** posteriorly
  - To the **ciliary body** anteriorly. (but choriocapillaris layer ends at **ora serrata**)
- ***Thickness***
  - Thickest at the posterior pole (**0.25**mm) ⇒ Greatest thickness at the macula
  - Gradually thins anteriorly (**0.10**mm).

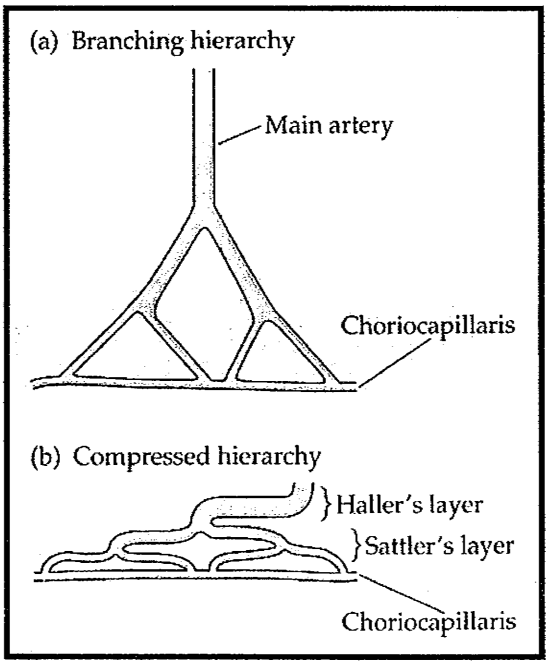
  Thickness ↓ by age (atherosclerosis), In myopia & Congenital glaucoma
- ***Colour*** → *Brown*
- ***Attached firmly***
  - To the **sclera**

    (1) at the *optic nerve* where the posterior ciliary arteries enter the eye.

    (2) at the points of exit of the *vortex veins*.
  - To **RPE**


Suprachoroidea
Haller's layer
Sattler's layer
Choriocapillaris
Bruch's membrane
Retinal pigment
epithelium


1
2
3
4
5
Bruch's membrane


(a) Branching hierarchy
Main artery
Choriocapillaris
(b) Compressed hierarchy
Haller's layer
Sattler's layer
Choriocapillaris

□ Structure:

- **Lamina fusca** (the suprachoroid) → 30 μm
  - ⇨ Consists of:
    - ***6-8 lamellae composed of elastic and collagenous fibers***
      - Posteriorly → dense & more adherent to each other & to sclera
      - Anteriorly. → looser (Choroidal detachment takes place anteriorly)
    - ***Melanocytes*** (Chromophobes) abundant in this layer & ↓ in number in the vascular layers
    - ***Smooth muscle fibers***, fibroblasts & endothelial cells.
  - ⇨ Contains: long and short ciliary arteries, and nerves.

The short posterior ciliary arteries have but a short course in the suprachoroid and extend directly to the choriocapillaris layer.

- **Blood vessel layer**: Vascular CT that has three components
  1) The outer vessel layer (of Haller), which *consists of **large veins*** that lead to the vortex veins, and have no valves.
  2) The middle vessel layer (of Sattler), which *consists of **medium-sized vessels*** and which contains a loose, collagenous stroma with numerous elastic fibers, fibroblasts, and melanocytes.
  3) The ***choriocapillaris***, which *consists of*
     - large (wide bore) fenestrated capillaries
       (responsible for choroidal flush after 10 sec. of Fluorescein injection)
     - form a dense, flat network extending. from the *optic disc* to the *ora serrata*.
       (Densest at the the macula → best nutrition of central cones)
     - has a distinct lobular structure with a central feeding arteriole & peripheral draining venules

- **Bruch's membrane (Lamina basalis choroideae = hyaloid membrane)** → 7 μm
  - Extension:
    - Anteriorly → to ***ciliary body*** → Continues as ***basement membrane of ciliary epithelium***
    - Posteriorly → to ***optic disc*** → fuses with ***intermediate tissue of khunt***
  - Source:
    - ***Choriocapillaris*** → Elastic lamina (outer layer) ⇒ ***Mesodermal***
    - ***RPE*** ⇒ Cuticular lamina (inner layer) ⇒ ***Ectodermal***.
  - Consists of:
    1) ***Basement membrane*** of choriocapillaris endothelium.
    2) ***Outer collagen layer***. (fine layer of collagen fibers)
    3) Layer of ***elastic Fibers***.
       (extends outward to form the supporting structure of the choriocapillaris)
    4) ***Inner collagen layer***.
       (originates from RPE & composed of collagen fibers surrounded by glycosaminoglycans)
    5) ***Basement membrane*** of RPE.

Blood supply:

Arterial:

The blood supply of the choroid is derived from

- The ***short posterior ciliary arteries***
  - Originate as two or three branches of the ***ophthalmic artery***.
  - These branches subdivide into 10 to 20 branches that perforate the sclera around the circumference of the optic nerve.
  - The majority pass at once into the choroid → communicate directly with choriocapillaris.
- The two ***long posterior ciliary arteries***
  - Originate as branches of the ***ophthalmic artery***
  - Perforate the sclera just medial and lateral to the optic nerve.
  - They extend forward in the suprachoroidal space (between the choroid and the sclera) on the medial and lateral sides of the globe to the ciliary body.
  - There each divides into two branches that extend circumferentially to form the ***major arterial circle of the iris*** that is located in the ciliary body.
    - ⇨ Branches extend anteriorly to the iris.
    - ⇨ Recurrent choroidal branches extend posteriorly to terminate in the choriocapillaris.
- The ***anterior ciliary arteries*** (via its recurrent branch)
  - Are the terminal branches of the two muscular arteries of each rectus muscle (except the lateral rectus muscle which has one muscular artery).
  - The anterior ciliary arteries bifurcate into vessels that penetrate the sclera and noupenetrating vessels that extend towards the cornea.
    - → The penetrating vessels
      - ⇨ provide the blood supply to the ***ciliary body***
      - ⇨ send ***recurrent*** branches to the anterior extremity of the choriocapillaris.
      - ⇨ send branches to the ***major arterial circle of the iris***.
    - → The nonpenebating vessels
      - ⇨ extend forward in the episclera as ***anterior conjunctival arteries***,
        - anastomose with posterior conjunctival arteries
        - terminate in the superficial (conjunctival) & deep (episcleral) pericorneal plexus

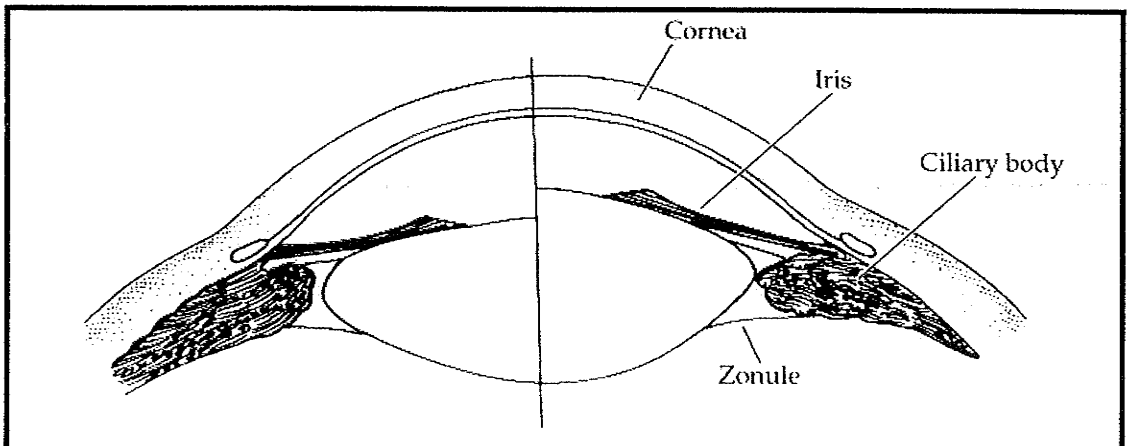
Venous:

- blood from the *choroid*, *ciliary body*. and *iris* is collected by a series of veins of increasingly larger diameter ⇒ ***Vortex veins*** (four or more) located behind the equator ⇒ superior and inferior ***Ophthalmic veins*** ⇒ ***Cavernous sinus***.
- ***Anterior ciliary veins*** → Drain ***ciliary muscle*** only. (it is also drained by vortex veins)

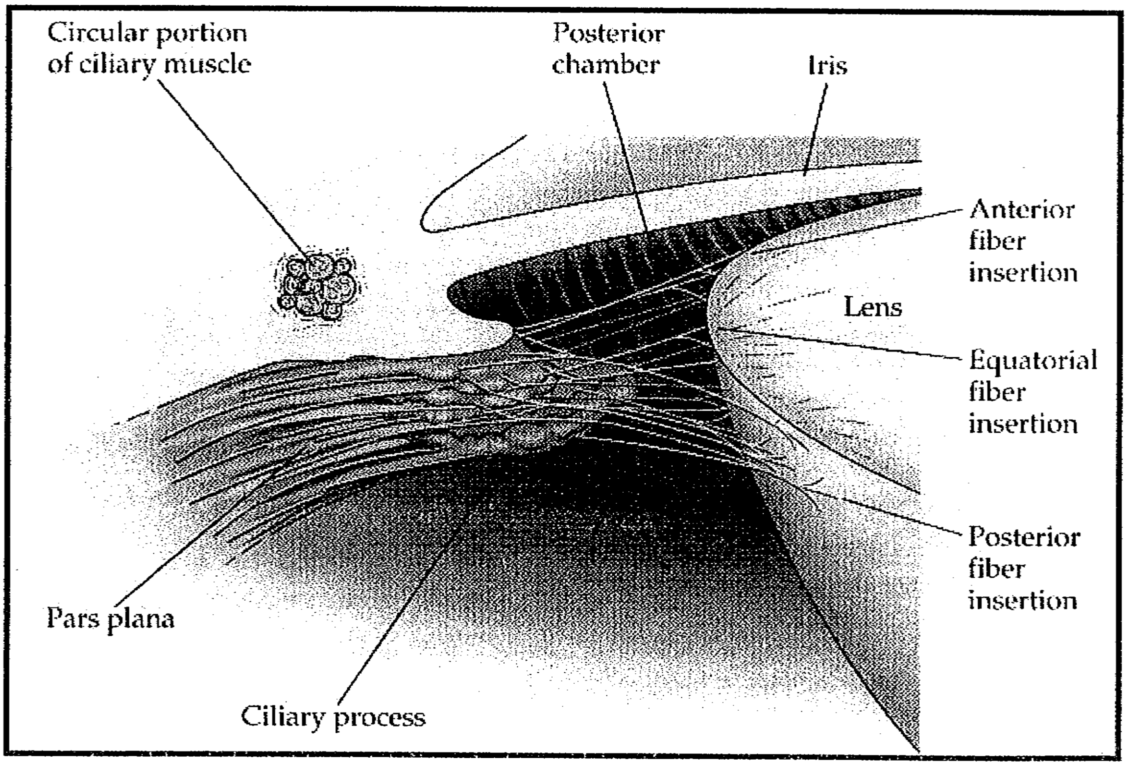
> N.B. *Ciliary congestion* in ***Acute congestive glaucoma*** is due to → impaired drainage via vortex veins → shift of venous drainage to Ant. ciliary veins → Engorged.

Nerve supply:

Mainly by ***sympathetic nerves*** around ICA that pass through the ciliary ganglion without synapse → distributed through the ***short ciliary nerves*** → **Pierce** the sclera around optic n. → As they **enter** the suprachoroid. they **lose** their myelin sheath & **branch** repeatedly to form a plexus. Nerve endings contact pigment cells & smooth muscle in the walls of arterioles.



Ciliary muscle relaxed—unaccommodated Ciliary muscle contracted—fully accommodated



The Ciliary Body

Definition:

- A ring of tissue about **6** mm wide that form the middle part of the middle coat of the eye
- extends from the ***scleral spur*** to the ***ora serrata***.

Function:

- Ciliary muscle ⇒ *Accomodation* & helps in *aqueous drainage*
- Ciliary process ⇒ *Aqueous secretion*

Gross:

Site:

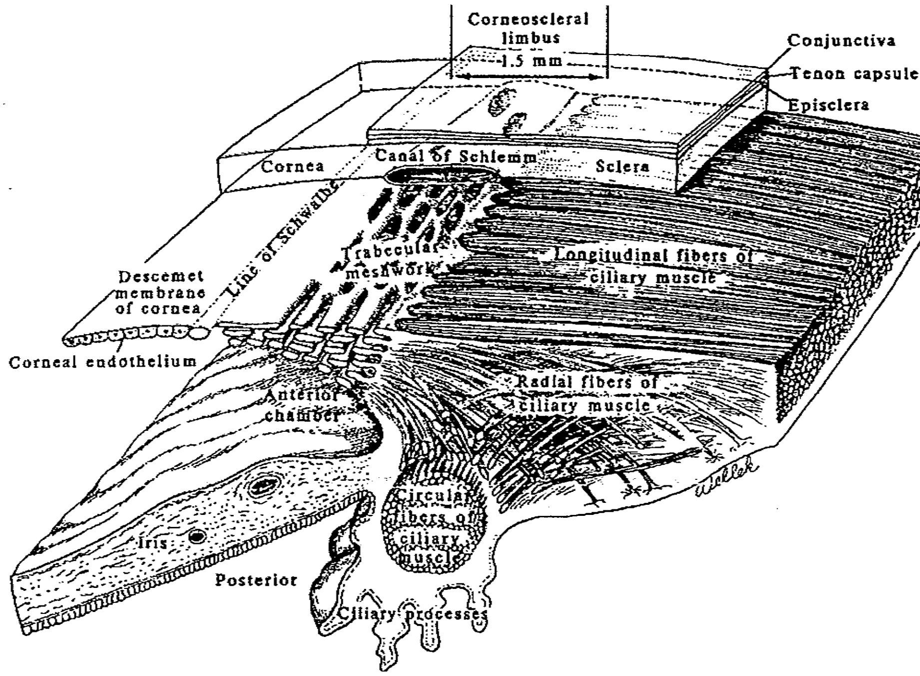
- Middle part of the uveal tract
- Extends from the ***scleral spur*** to the ***ora serrata***
- Posterior limit from limbus → **Nasal** = **6.5** **Temporal** = 7.5 **superior & inferior** = 7 mm

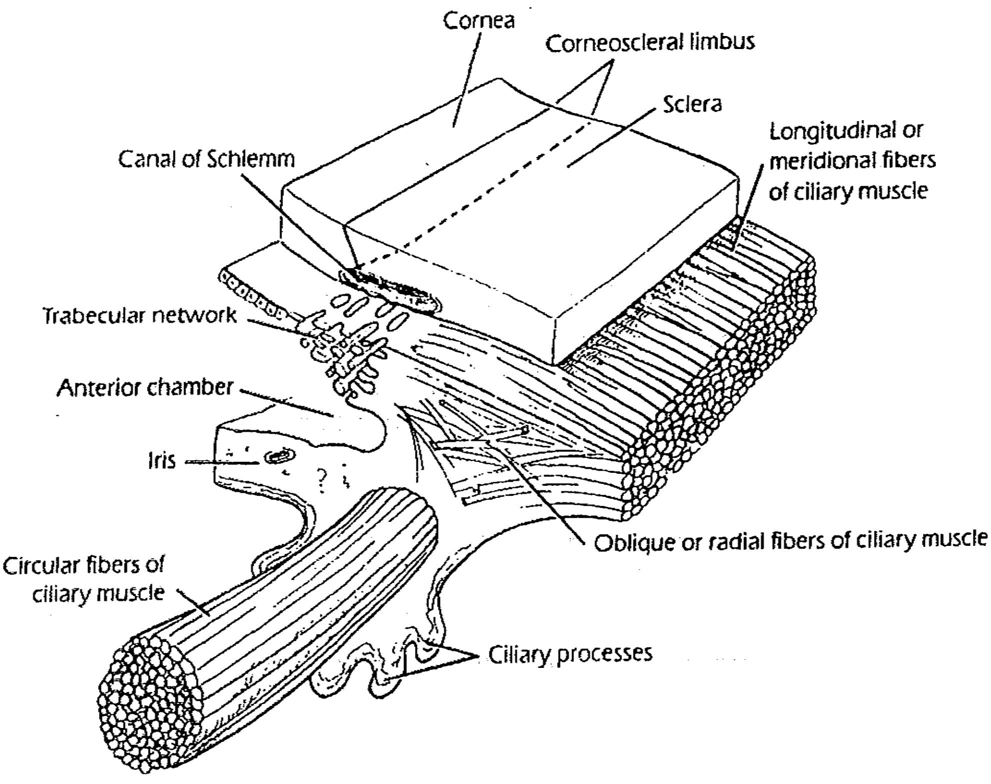
Colour: *Black (Melanocytes are larger & darker than those of the choroid)*

Shape: *Ring shaped (Nasal side = 5.9 mm Temporal side = 6.7 mm)*

Sagital section: → *Triangular* (base faces anterior chamber, apex blends with the choroid)

- **Anterior side**: (Base) : Faces the anterior chamber
  - ⇨ outer part → shares in the formation of angle (may be covered by trabecular meshwork)
  - ⇨ middle part → receives iris insertion
  - ⇨ inner part
- **Outer side**: Corresponds to the **ciliary muscle** & separated from the **sclera** by supraciliary space
- **Inner side**:
  - ⇨ Pars plana → Posterior ⅔ (Smooth)
  - ⇨ Pars plicata → Anterior ⅓ (Ciliary processes)


Corneoscleral limbus
1.5 mm
Conjunctiva
Tenon capsule
Episclera
Cornea
Canal of Schlemm
Sclera
Line of Schwalbe
Trabecular meshwork
Longitudinal fibers of ciliary muscle
Descemet membrane of cornea
Corneal endothelium
Anterior chamber
Radial fibers of ciliary muscle
Circular fibers of ciliary muscle
Iris
Posterior
Ciliary processes


Cornea
Corneoscleral limbus
Sclera
Longitudinal or meridional fibers of ciliary muscle
Canal of Schlemm
Trabecular network
Anterior chamber
Iris
Oblique or radial fibers of ciliary muscle
Circular fibers of ciliary muscle
Ciliary processes

☐ **Structure:** The ciliary body is divided into uveal and epithelial portions.

- **Uveal portion:** adjacent to the sclera and includes:
  - **Lamina Fusca** (the suprachoroid) → Collagen fibers + Melanocytes + Fibroblasts
  - Vessel layer → **circulus arteriosus iridis major & veins.** NB. No choriocapillaris.
  - **Ciliary muscle** *(Smooth muscle)*

    1) the **longitudinal (meridional)** fibers (Brucke muscle)
       - The outermost portion
       - parallel to the surface of the overlying sclera
       - constitute the main bulk of the muscle.
       - Originate from the ***scleral spur*** & near by ***trabecular meshwork*** by tendinous fibers (ciliary tendon) → End posteriorly in a branching stellate forms (muscle stars) in the ***suprachoroidal*** lamina (as far as the equator or even beyond)

       ⇒ Action: contraction ⇒ retracts the scleral spur and enlarge the canal of Schlemm → aqueous drainage

    2) the **radial (oblique)** fibers
       - The middle portion
       - Originate from the anterior portion of the longitudinal fibers & run obliquely to become continuous with circular fibers

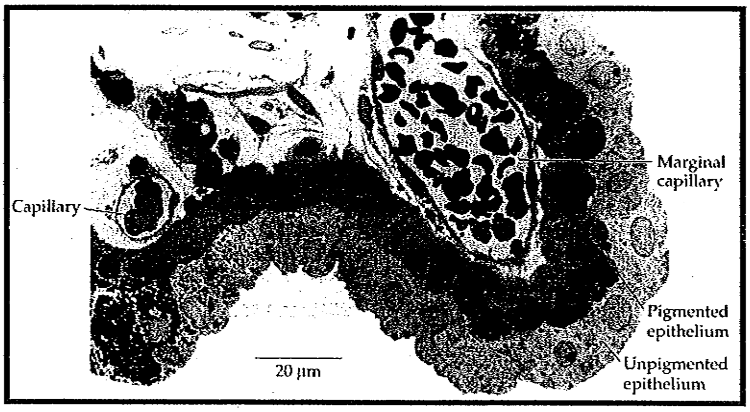
    3) the **circular (sphincteric)** fibers (Muller muscle)
       - The innermost portion
       - parallel to the lens equator.
       - circulus arteriosus iridis major lies in front of it

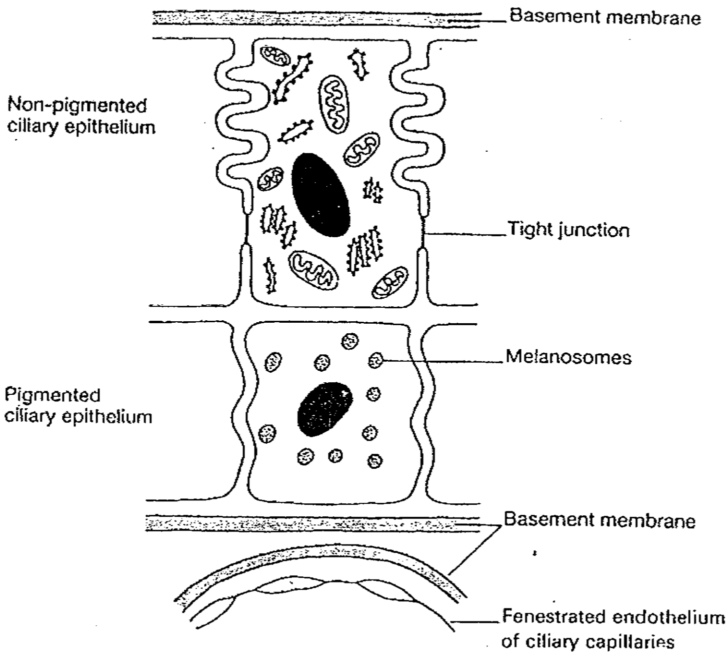
The CT stroma of the ciliary muscle

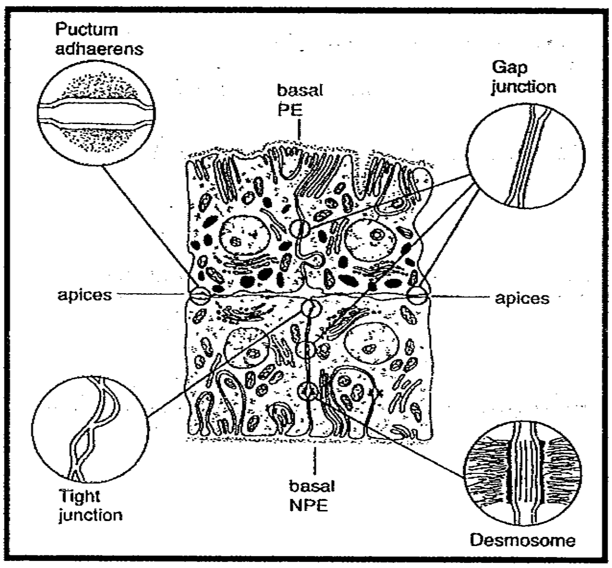
- Formed of ⇒ Collagen fibers
- Contains ⇒ melanocytes + blood vessels & nerves
- Stroma
  - ➪ between longitudinal fibers it is ***continuous with the suprachoroid,***
  - ➪ between radial fibers is ***dense***
  - ➪ between circular fibers is ***loose*** *(resembling & continuous with that at the iris root)*

Motor innervation (Parasympathetic)

Edinger-Westphal nucleus of the oculomotor (N III) nerve ➪ ***Preganglionic fibers*** pass from the inferior division of occulomotor ➪ ***ciliary ganglion*** (synapse) ➪ ***postganglionic fibers*** ➪ ***short ciliary nerves*** (6-20) ➪ ciliary muscle and sphincter pupillae muscle.


Marginal capillary
Capillary
Pigmented epithelium
Unpigmented epithelium
20 μm


Basement membrane
Non-pigmented ciliary epithelium
Tight junction
Melanosomes
Pigmented ciliary epithelium
Basement membrane
Fenestrated endothelium of ciliary capillaries


Puctum adhaerens
basal PE
Gap junction
apices
apices
Tight junction
basal NPE
Desmosome

- **Epithelial portion:** adjacent to the posterior chamber and includes:
  - ***Pars plana (orbiculus ciliaris)***
    - The posterior 4 mm of the inner side of the ciliary body.
    - Its posterior margin corresponds to the retinal **ora serrata**. At which:
      - ⇒ **Sensory retina** abruptly changes into → single layer of **nonpigmented epithelium** of the ciliary body.
      - ⇒ **RPE** continues forward as → the **pigmented epithelium** of the ciliary body.
      - ⇒ **Internal limiting membrane** continues as → the **BM of nonpigmented epith.**
    - Surgical instruments are introduced into the vitreous cavity or into the crystalline lens through the pars plana.
  - ***Pars plicata (corona ciliaris)***
    - The anterior **2** mm of the inner side of the ciliary body.
    - It is formed of the **ciliary processes:**
      - → Definition: Vascular core of Connective tissue covered with a layer of pigmented epithelium then a layer of nonpigmented epithelium
      - → Number: → **60 – 70**
      - → Dimention: each of which is about **1** mm high and **0.5** mm wide.
      - → Colour: Almost white, in contrast to the black valleys in between.

The inner ***Nonpigmented epithelium***	The outer ***Pigmented epithelium***
It is the anterior continuation of the **sensory retina**. (from the inner layer of optic cup)	It is the anterior continuation of the **RPE**. (from the outer layer of optic cup)
Its **basement membrane** is • continuous with the retinal internal limiting membrane • located on the inner side of the cell that faces the posterior chamber.	Its **basement membrane** is • the continuation of the inner cuticular layer of bruch's membrane • located on the outer side of the cell that faces the sclera.
Continuous anteriorly with the **posterior epithelium** of the iris	Continuous anteriorly with **dilator ms** of the iris
Structure • Single layer of cubical – columnar cells • Have prominent **Golgi complexes** (like other secreting glandular cells) & **Mitochondria**.	Structure: Differ from RPE in that: • ↓ Height • ↑ Pigment (mask the nucleus) • Absent processes
Aqueous humor & hyaluronic acid are secreted through the apices of the nonpigmented epithelial cells of the ciliary processes.	
The pigmented & nonpigmented epithelium are in an **apex to apex** apposition → aqueous humor when secreted must pass between the nonpigmented cells to reach the posterior chamber.	

At the anterior termination of the choroid ⇒ Bruch membrane divides:
- ➪ The ***elastic layer*** derived from **choroid** disappears
- ➪ The ***inner cuticular layer*** which originates from the **RPE**, continues forward to the iris root as the basement membrane of the pigmented epithelium of the ciliary body.

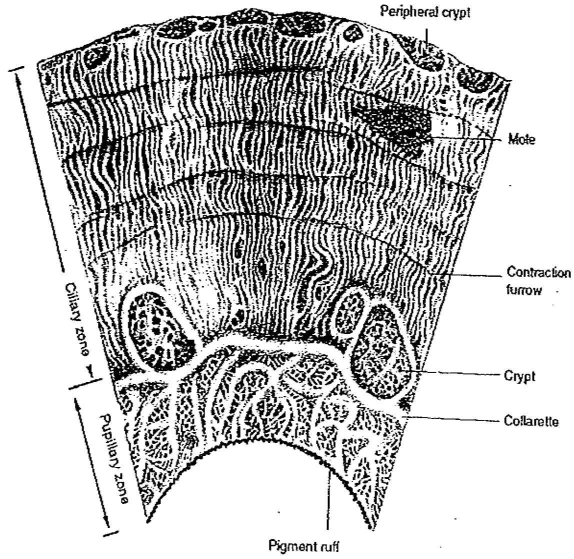
Blood Supply:

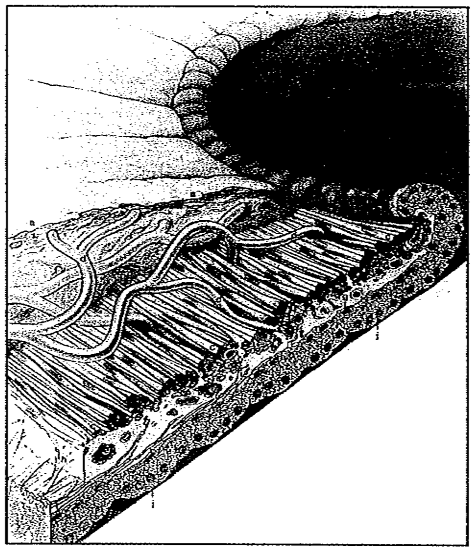
- **Arterial** ⇒ ***Circulus arteriosus iridis major*** formed by the two long ciliary arteries and the penetrating branches of the seven anterior ciliary arteries.
- **Venous** ⇒
  - blood from the *choroid, ciliary body.* and *iris* is collected by a series of veins of increasingly larger diameter ⇒ ***Vortex veins*** (four or more) located behind the equator ⇒ superior and inferior ***Ophthalmic veins*** ⇒ ***Cavernous sinus.***
  - ***Anterior ciliary veins*** → Drain ***ciliary muscle*** only. (it is also drained by vortex veins)

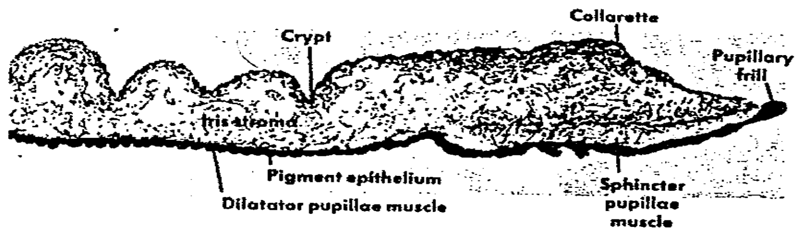
N.B. ***Ciliary congestion*** in ***Acute congestive glaucoma*** is due to → impaired drainage via vortex veins → shift of venous drainage to Ant. ciliary veins → Engorged.

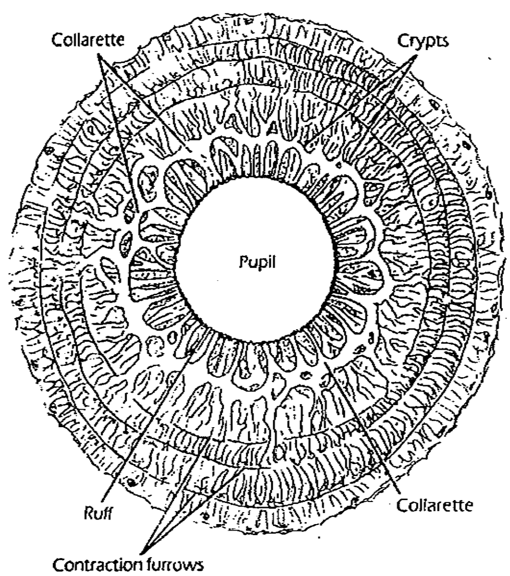
Nerve supply:

- To the ciliary muscle : (Parasympathetic)
  ⇒ ***Edinger-Westphal nucleus*** of the oculomotor (N III) nerve ⇒ ***Preganglionic fibers*** pass from the inferior division of occulomotor ⇒ ***ciliary ganglion*** (synapse) ⇒ ***postganglionic fibers*** ⇒ ***short ciliary nerves*** (6-20) ⇒ ciliary muscle and sphincter pupillae muscle.
- To uveal blood vessels: (Sympathetic) ⇒ through ***short ciliary nerves.***

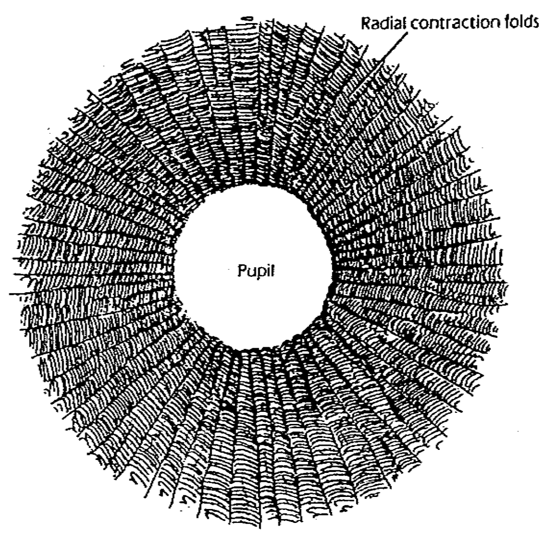








Anterior Iris surface



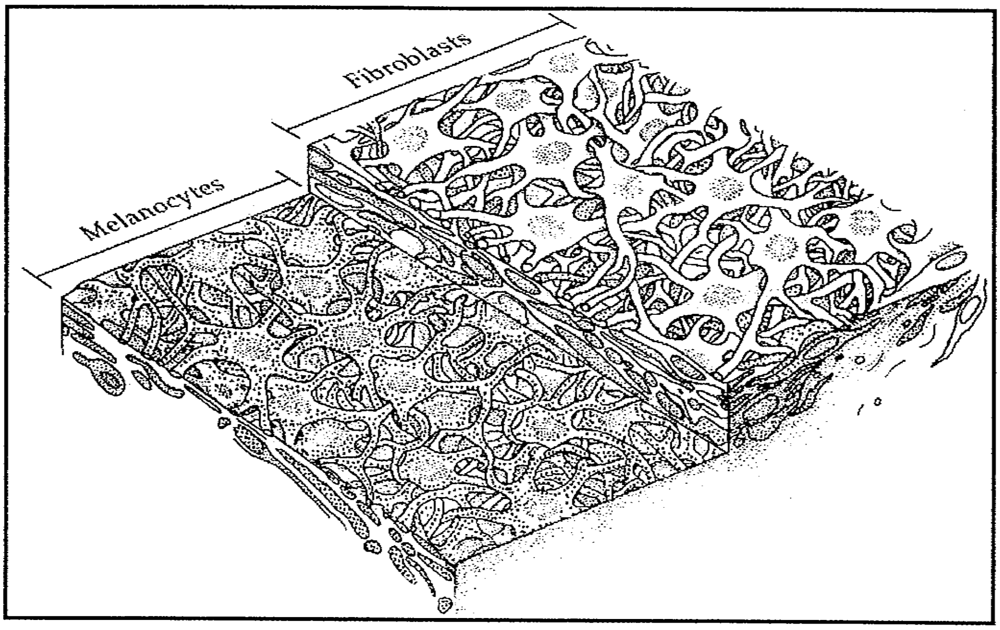
Posterior Iris surface

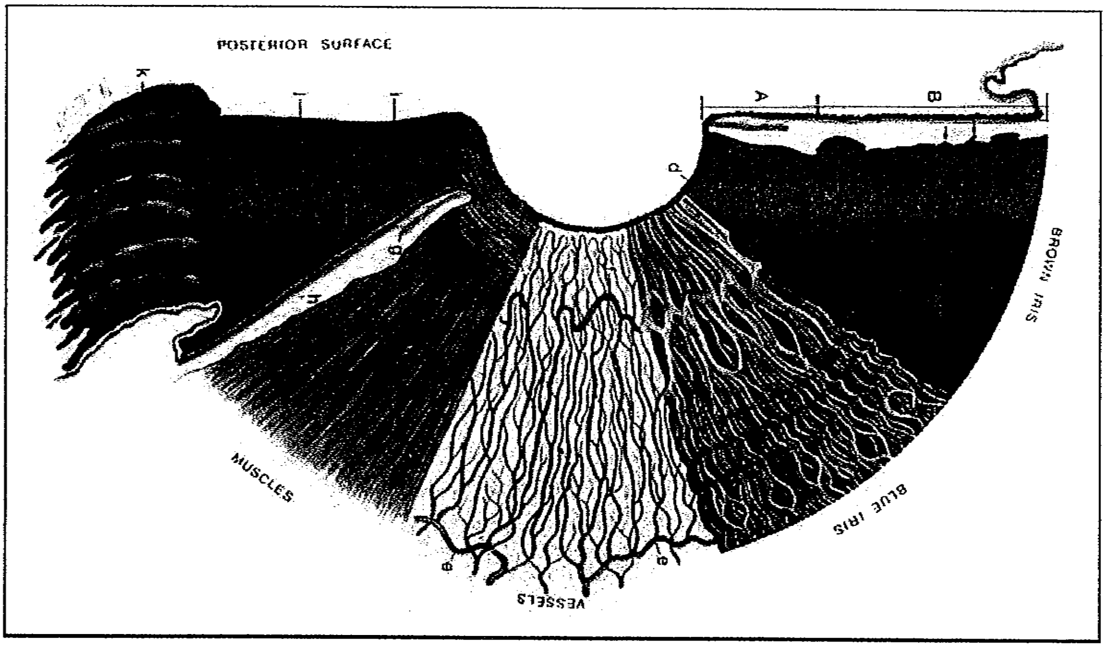
The Iris & Pupil

- **Definition:** The most anterior part of the uveal tract that forms a diaphragm in front of the lens & ciliary body and separating the anterior chamber from the posterior chamber.

- **Gross:**
  - **Diameter:** 12 mm
  - **Thickness:** 0.5 mm (*Thickest* at the collarette & *Thinnest* at the root)
  - **Ciliary border:** the iris inserts into the middle of the anterior surface of the ciliary body.
  - **The pupil:** a circular opening located slightly to the nasal side of the iris & controls the amount of light entering the eye.
  - **The posterior iris surface:** rests upon the anterior surface of the lens. Without this support the iris is tremulous (iridodonesis).
    - Black or Dark brown
    - By naked eye → Smooth
    - By low magnification
      - Radial furrows (Schwalbe's contraction folds & Schwalbe's structural furrows)
      - Circular furrows (Cross structural furrows & are most developed at iris root)
  - **The anterior iris surface:** divided by the collarette into a central pupillary zone. from which the anterior border layer is absent & a peripheral ciliary zone. Iris pattern.
    - The *collarette:*
      - ⇨ A zigzag like circular ridge about **1.6** mm from the pupillary margin.
      - ⇨ Marks the site of the **Circulus arteriosus iridis minor.**
      - ⇨ **Fuch's Iris crypts:** Pit like depressions in the region of circulus minor → over it the superficial tissue layers are deficient → Fluid passes easily out of iris vessels during pupillary constriction & dilatation.
      - ⇨ It is the site of attachment of the **pupillary membrane** in embryonic life. Atrophy of the pupillary membrane begins in the **7th** gestational month and is usually completed by **8½** months, sometimes leaving behind a few delicate strands that extend from the collarette to the anterior lens capsule.
    - The ***pupillary zone***
      - ⇨ Relatively **flat.**
      - ⇨ Its **width varies** with degree of atrophy of the anterior border layer & with pupillary dilation.
      - ⇨ **Pigment frill** is usually seen at the pupillary margin. (extended posterior pigment epithelium)
    - The ***ciliary zone***
      - ⇨ Contains many **radial ridges** → a gossamer appearance.
      - ⇨ **Concentric contraction furrows** may be seen in blue irises.
      - ⇨ The **Iris colour** depends on the amount of melanin in the anterior border layer:
        - If slight amount → reflection from the pigment of the pigmented epitheium causes scattering and thus a **blue** colour.
        - If moderate amount → the iris is **hazel.**
        - If large amount → the iris is **brown.**

N.B. In newborn, neither collarette nor crypts are present, they develop later in life


Melanocytes
Fibroblasts


POSTERIOR SURFACE
A
B
MUSCLES
VESSELS
BLUE IRIS
BROWN IRIS

☐ **Structure:** The iris consists of two layers:

Stroma: located anteriorly & originating from mesoderm, Divided into:

- ***Anterior border layer***
  - A condensation of CT, pigment & nonpigmented cells derived from anterior stroma
  - This layer develops maximally about the 7th month of fetal life. Thereafter, **generalized atrophy** in the pupillary zone & **irregular atrophy** in the ciliary zone occurs ➪ So it is absent in the pupillary zone (1.5 mm wide) & only present in the ciliary zone.

    ➪ Absent at the crypts & Thinned over the contraction furrows

    > **Iris crypts**: Pit like depressions due to irregular atrophy of the anterior border layer in the ciliary zone.

    ➪ It is responsible for the colour of the iris
    - If it is thin with few melanocytes → Blue iris
    - If it is thick & richly pigmented → Brown iris

    ➪ In brown irises the surface is smooth and heavily pigmented, in blue or hazel irises it is irregular with crypts.

    ➪ The anterior border layer ends abruptly at the iris root, but spoke like iris processes may continue to the Schwalbe's line & scleral spur.

- ***Stroma proper***:
  - Has a similar appearance irrespective of the color of the iris.
  - It is visible in the pupillary zone and in the depth of iris crypts.
  - Consists of
    - ***bundles of collagen fibrils*** arranged in columns around

      ➪ ***Blood vessels***

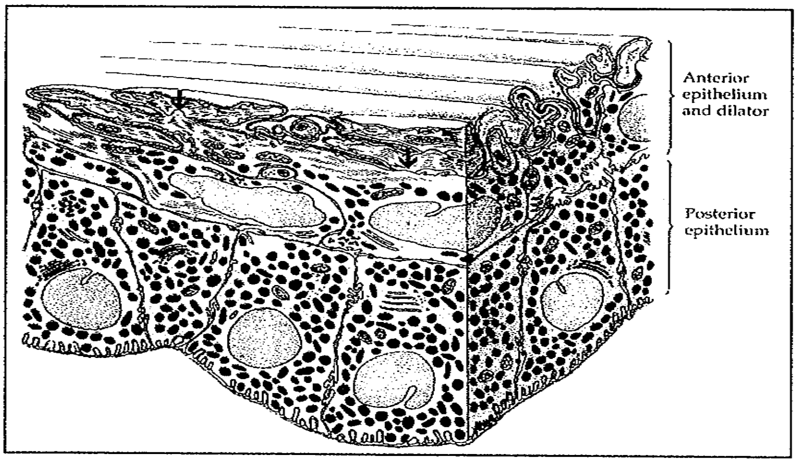
      ➪ ***Nerves***

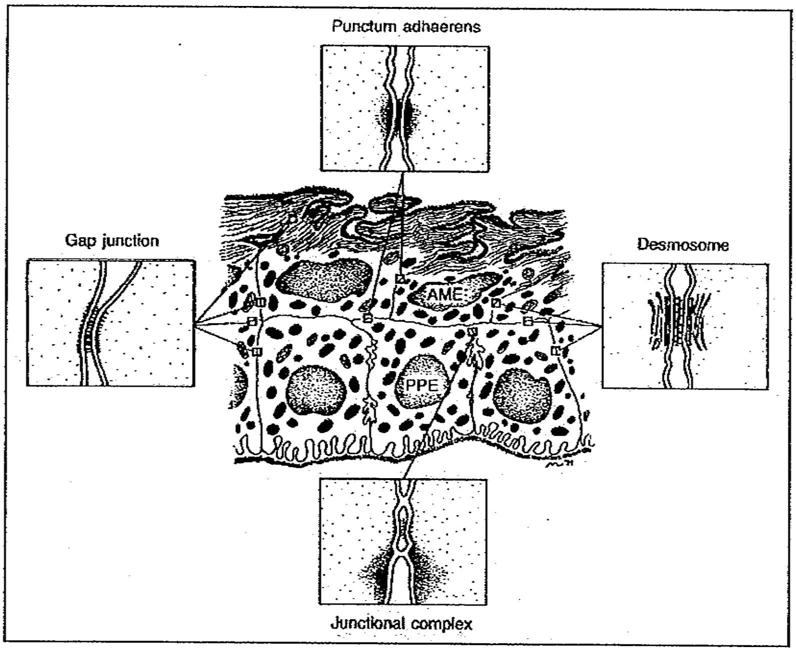
      ➪ ***Fibroblasts*** *→ Most common stromal cells*

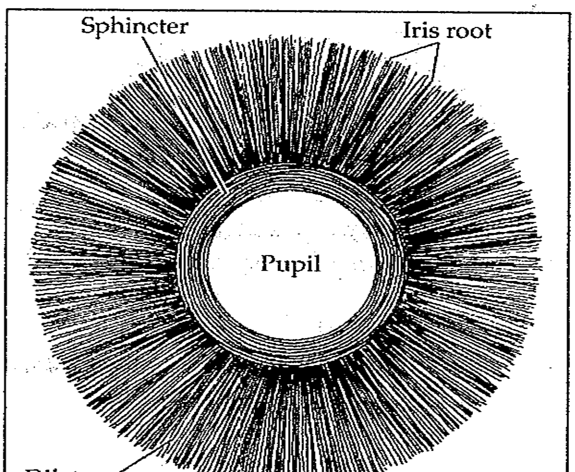
      ➪ ***Melanocytes*** *→ branching cells with long processes form networks especially around vessels, contain melanin granules & oval nonpigmented nucleus*

      ➪ ***Clump cells*** *→ Rounded pigment cells dervied from anterior pigment epithelium, present near sphincter pupillae, contain granular cytoplasm with melanin granules & small nucleus*

      ➪ ***Other cells*** (Lymphocytes, macrophages, plasma cells, mast cells)
    - all enmeshed in a hyaluronidase-sensitive ***glycosaminoglycan***.
  - Contains ***more elastic tissue & fewer pigment cells*** than anterior border layer.


Anterior epithelium and dilator
Posterior epithelium


Punctum adhaerens
Gap junction
Desmosome
AME
PPE
Junctional complex

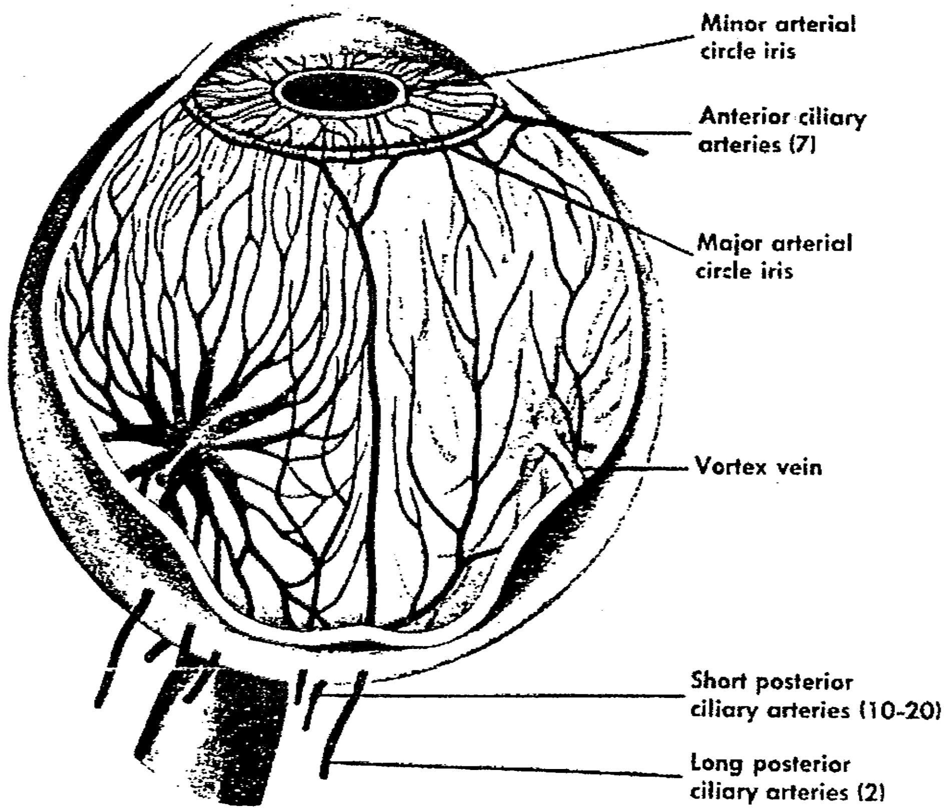

Sphincter
Iris root
Pupil
Dilator

Pigmented epithelium: located posteriorly & originating from neural ectoderm.

- The ***anterior layer of pigment cells***
  - Derived from outer layer of optic vesicle
  - Consists of
    - Apical portion (**pigment** portion)→ Contain nucleus & melanin granules
    - Basal portion (**myoepithelial** portion) → contractile elongated process form a thin sheet of muscle (the dilator pupillae muscle)
- The ***posterior layer of pigment epithelium***
  - Derived from Inner layer of optic vesicle
  - Covered on its lenticular surface with a BM (continuous with that of the retina and the ciliary body)
  - Charachterized by ⇒ *high amounts of melanin granules, Basal nucleus & basal infoldings, lateral cell walls joined by desmosomes*
  - ***Pigment frill***: *(Physiological ectropion uvae)*
    - Fringe of black pigment often present at the pupillary margin,
    - Due to slight extension of the posterior pigmented epithelium around the pupillary edge. (That ectodermal pigment epithelium represent the anterior extremity of the optic cup)

Smooth muscles:

	Sphincter pupillae muscle (N III)	***Dilatator pupillae muscle*** (sympathetic)
Definition	1 mm wide smooth muscle	A thin sheet of smooth muscle (myoepithelium)
Located	In the *pupillary zone of the posterior stroma*, encircling the pupil	In the *ciliary zone between the stroma & the posterior layer of the pigmented epithelium*. extending from the ***iris root*** to the ***sphincter ms.*** *It is an outgrowth from the basal process of epithlial cells that lie peripheral to Van Michel's spur*
Structure	It doesnt lie loose in the stroma, but it **adheres firmly to the surrounding structures** by CT bundles & vessels → After iridotomy, the remaining portion of the sphincter doesnt contract up & the pupil can still react to light.	It sends junctional fibers attach it to ▫ The stroma of the iris root (Grunert spur) ▫ Peripheral border of sphincter (Michel spur) ▫ Midway along the length of sphincter (Fuch's spur) It is poorly developed in newborn → difficult to dilate the pupil with mydriatics
Action	▫ Pupillary constriction ▫ Pull pigmented edge anteriorly → ↑ Physiological ectropion uvae	▫ Pupillary dilataion
Nerve supply	Parasympathetic (via short ciliary nerves)	Sympathetic (via long ciliary nerves)
Origin	**Neural ectoderm** of the outer layer of optic cup (anterior epithelium)	


Minor arterial circle iris
Anterior ciliary arteries (7)
Major arterial circle iris
Vortex vein
Short posterior ciliary arteries (10-20)
Long posterior ciliary arteries (2)

☐ Blood supply: (Mention it with the structure)

- **Arterial:**
  - ➪ Two long posterior ciliary arteries and the seven anterior ciliary arteries ➪ ***circulus arteriosus iridis major*** (arterial) (in the ciliary body) ➪ radial vessels in the stromal layer (pass radially in a corkscrew pattern towards the pupillary margin, causing the meridional striations of the ciliary portion of the iris) ➪ *Circulus arteriosus iridis minor* (arterial + Venous) (At the collarette)
  - ➪ The vessels have a thick *collagen adventitia*, a thin *muscularis layer* & no *internal elastic lamina*.
- **Venous:**
  - The endothelial cells of the veins have a perivascular sheath.
  - They drain into the ***vortex veins***.
    (Circulus venous iridis minor drains into vortex veins as there is no circulus venous iridis major)
- **Capillaries:**
  - The ***capillary endothelium*** is
    - *Non fenestrated.*
    - with *Tight junctions* that prevent the passage of large molecules.
  - ***Blood-aqueous barrier***: formed by :
    1. This *vascular endothelium*. (nonfenestrated + zonula occludentes)
    2. The *tight junctions of the ciliary epithelium*. (mainly)

NB. The ciliary body vessels, like those of the choroid are fenestrated.

☐ Nerve Supply:

The iris is richly supplied with non-myelinated nerves from the ***short ciliary*** & ***long ciliary*** nerves

- **Sensory:**
- **Autonomic:**
  - **Dilatator pupillae muscle** (sympathetic) nerves accompanying the *long ciliary nerves*.
  - **Sphincter pupillae muscle** (parasympathetic)
    - ➪ ***Edinger-Westphal nucleus*** of the oculomotor (N III) nerve ➪ ***Preganglionic fibers*** pass from the inferior division of occulomotor ➪ ***ciliary ganglion*** (synapse) ➪ ***postganglionic fibers*** ➪ ***short ciliary nerves*** (6-20) ➪ ciliary muscle and sphincter pupillae muscle.
  - **Arteries of the iris** (sympathetic) is caried by the *short ciliary nerves*.

> **Iris** & **ciliary body** are → extremely **sensitive** to pain (from the ciliary nerves)
> **choroid** is → **insensitive** to pain (Laser to retina is not painful to the patient)

Retina

Thin **transparent** membrane, **purplish red** due to:

→ The visual purple of the rods (disappear after death ⇒ becomes white opaque)

→ The dark choroid appears through it (if not detached)

Retinal pigment epithelium (From outer layer of optic vesicle)

- ***Base*** (plasma membrane, mitochondria)
- ***Body*** (nucleus, endoplasmic reticulum, lipofuscin)
- ***Apex*** (pigment, ingested outer segment (phagosomes)
    1) Microvilli
    2) Lateral terminal bars (zonula adherence and zonula occludens)

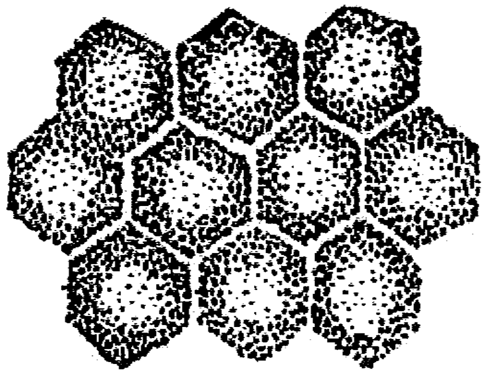
Sensory retina (From inner layer of optic vesicle)

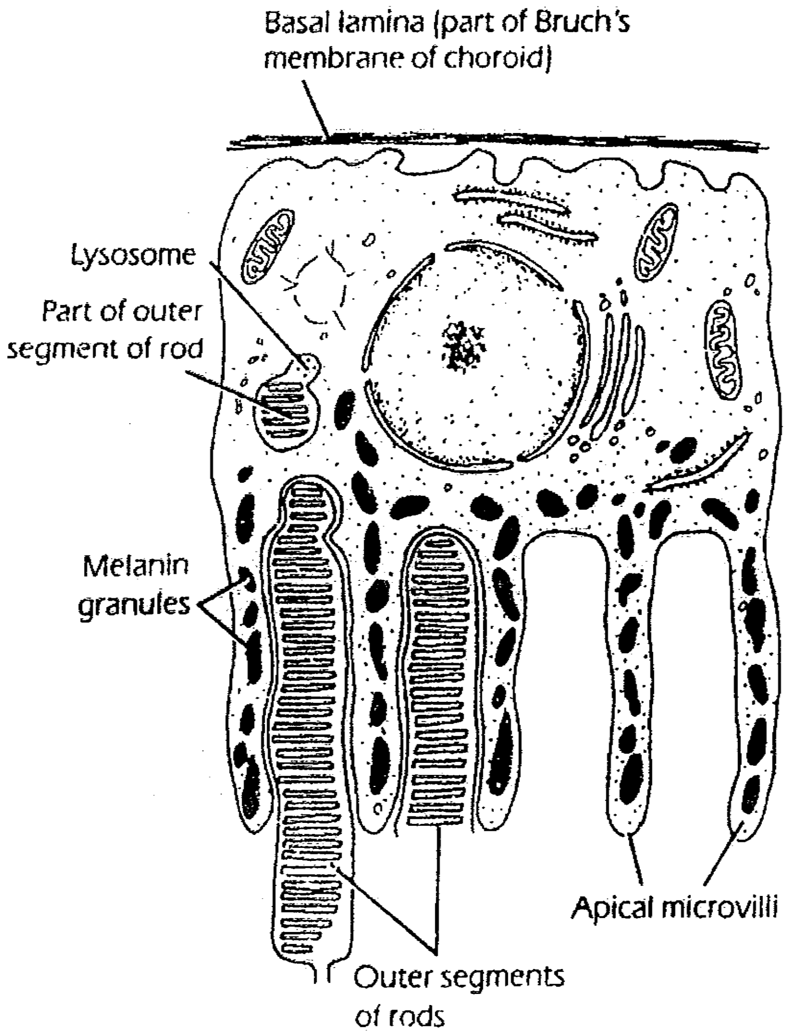
- ***Photoreceptor*** cells (nuclei form the outer nuclear layer)
    - Outer segment (rods and cones)
    - Cilium
    - Inner segment
        1) Ellipsoid
        2) Myoid
    - Outer fiber (surrounded by terminal bars of muller cells)
    - Cell body(nucleus) the outer nuclear layer
    - Inner fiber
    - Synaptic vesicle

- Modulator cells (nuclei form the inner nuclear layer)
    - ***Bipolar***
        1) Midget
        2) Flat midget
        3) Diffuse
        4) Interplexiform
    - ***Horizontal***
    - ***Amacrine***

- Transmitter cells
    - ***Ganglion cells*** (nerve fiber layer = axons of ganglion cells)

- Skeletal support
    - ***Muller*** cells (nuclei within inner nuclear layer)
    - Internal limiting membrane (retinal basement membrane)
    - Accessory glia
        1) Small ***astrocytes***
        2) ***Oligodendrocyte*** like cells




Basal lamina (part of Bruch's membrane of choroid)
Lysosome
Part of outer segment of rod
Melanin granules
Apical microvilli
Outer segments of rods

Retinal Pigment Epithelium

Definition:

- A single layer of about 5 million cells
- Firmly attached to its basement membrane (of bruch's membrane)
- Extends from the ***optic n. margin*** posteriorly to the ***ora serrata*** anteriorly (where it continues forward as the pigmented ciliary epithelium)

Origin: *neuro-ectoderm* (outer layer of optic cup)

Structure:

- **Basement membrane** → firmly attached to the cuticular portion of the Bruch membrane.
- **Pigment epithelial cells:**
  - **Flat section**:
    - Cells are ***hexagonal***; individual cells may have 4-8 sides.
    - The cells fit together like ***cobblestones*** in a regular arrangement.
  - **Cross section**:

    In the region beneath the central portion of the sensory retina → cells are slender and tall.
    In the periphery → They are more cuboidal.
    They are divided into:

    - **Base** → contains
      1) prominent *infoldings of the basal plasma membrane*,
      2) many *mitochondria*, and little or no pigment.
    - **Body** → contains
      1) *nucleus*,
      2) *organelles*,
      3) *lipofuscin*. (prominent in the RPE underlying the central retina in individuals > 30 years.)
      4) *melanin granules.*
    - **Apex**

      → Topped with ***microvilli*** that embed the outer segments of rods and cones in glycosaminoglycans without specialized attachement.

      → The apical cytoplasm contains:

      ⇒ ovoid ***pigment granules*** and

      ⇒ partially digested outer segment discs (***phagosomes***).

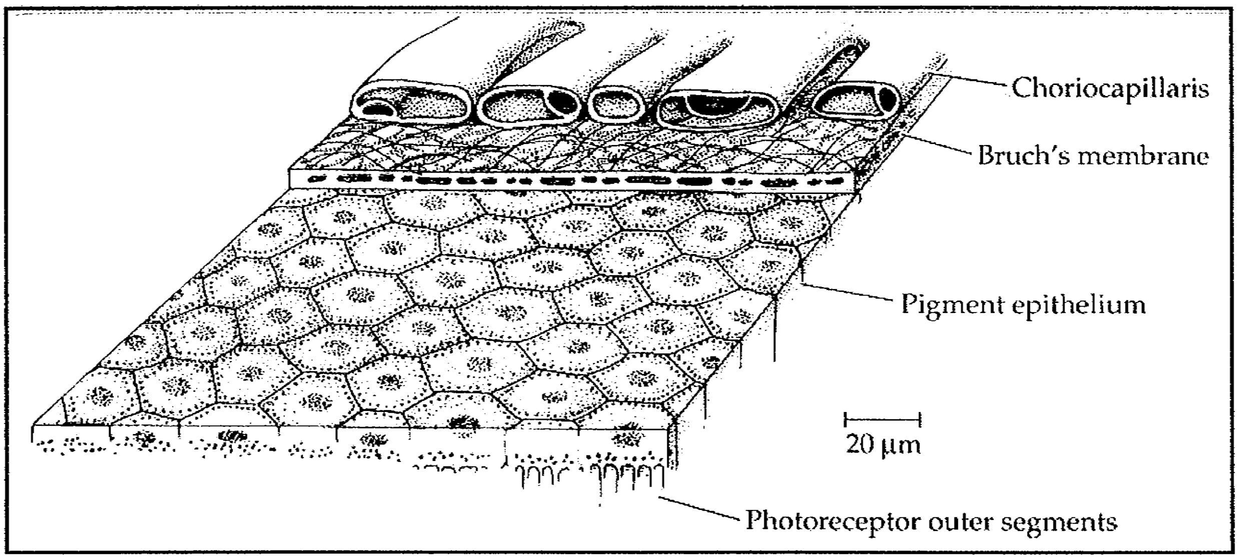
      → The lateral surfaces of the apices of adjacent cells (but not the microvilli) are bound together by ***terminal bars*** composed of:

      ⇒ Basilar portion (zonula adherens).

      ⇒ Apical portion (zonula occludens).

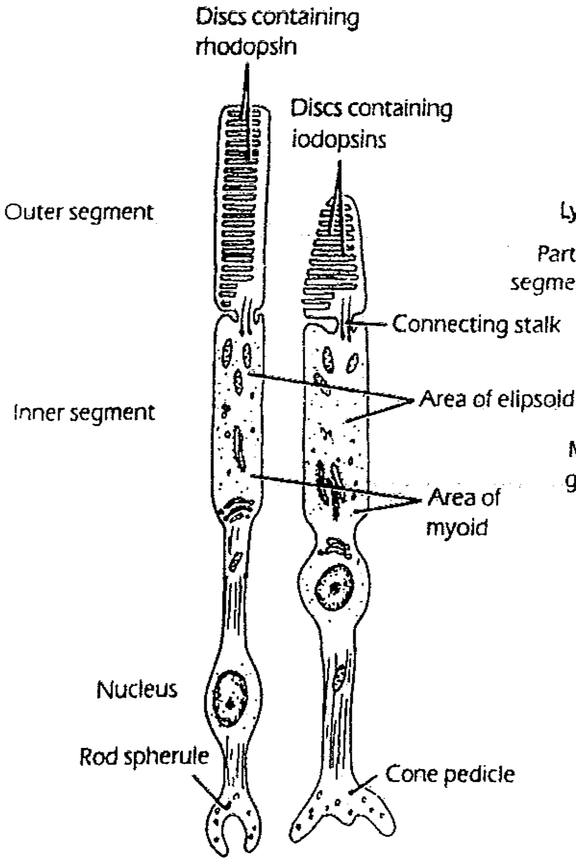
Blood- retinal barrier.

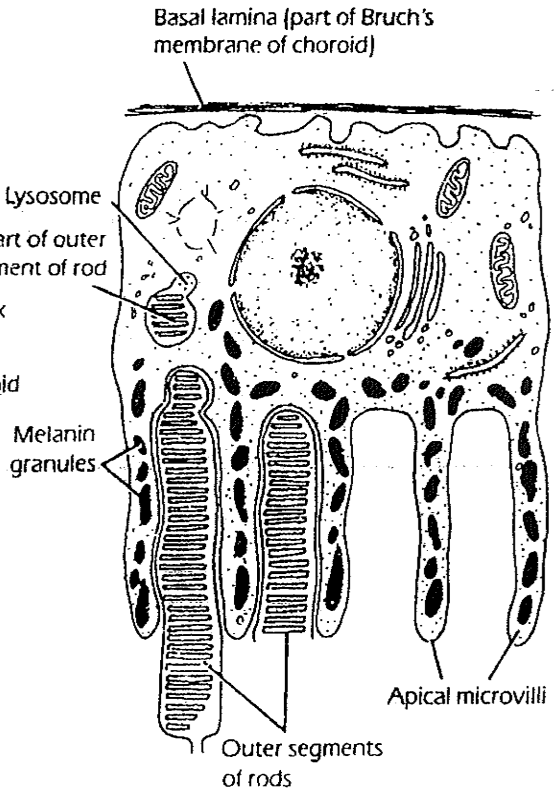
1- Junctions between apical portion of RPE.
2- Nonfenestrated retinal blood vessels.

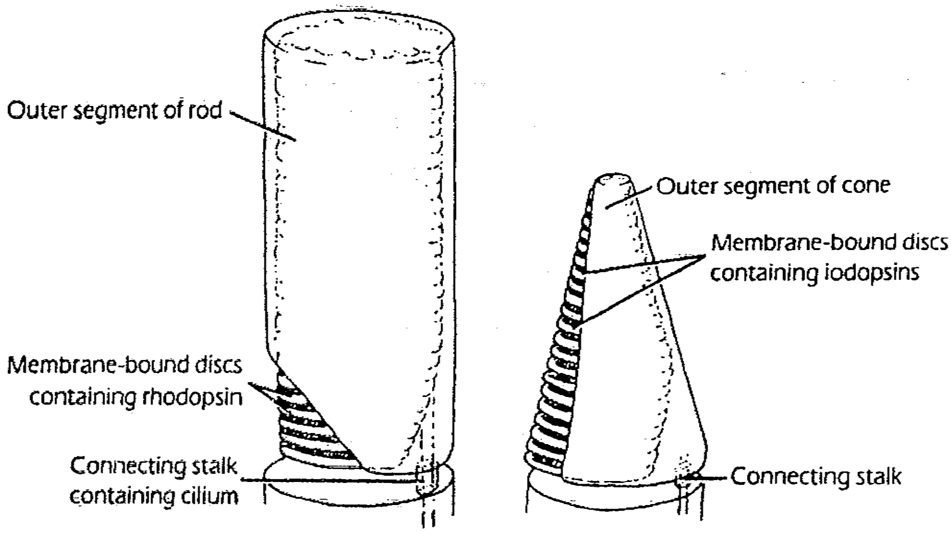

Choriocapillaris
Bruch's membrane
Pigment epithelium
20 μm
Photoreceptor outer segments

Applied anatomy:

- In **Fluorescein Angiography**, the *obscured fluorescence* from the underlying choroid is due to ***lipofuscin*** and the ***melanin*** in RPE.
- On **ophthalmoscopic examination**
  - ⇨ The *granular appearance* of the fundus is due to:
    1) RPE cells contain variable amounts of ***melanin***.
    2) In each cell, ***melanin*** is less in the center and more in periphery
  - ⇨ The *choroidal ring* around the optic disc is due to:
    1) RPE cells may not contain melanin granules.
    2) RPE falls short of the basal lamina of the choroid.
    3) RPE cells may be heaped up at the edge of the disc.
  - ⇨ The *darker colour of the fovea* is because:
    1) RPE are higher & contain more melanin.
    2) Retina is more thin.
    3) Choroid is more thick with rich blood supply.
- **Retinal detachment** occure between sensory retina and RPE because:
  1) RPE is firmly adhernt to choroid
  2) RPE is loosely adhernt to rods & cones
     - No junctional complex
     - No specialized adhesion molecules in the interphotoreceptor matrix


Discs containing rhodopsin
Discs containing iodopsins
Outer segment
Connecting stalk
Inner segment
Area of elipsoid
Area of myoid
Nucleus
Rod spherule
Cone pedicle


Basal lamina (part of Bruch's membrane of choroid)
Lysosome
Part of outer segment of rod
Melanin granules
Apical microvilli
Outer segments of rods


Outer segment of rod
Membrane-bound discs containing rhodopsin
Connecting stalk containing cilium
Outer segment of cone
Membrane-bound discs containing iodopsins
Connecting stalk

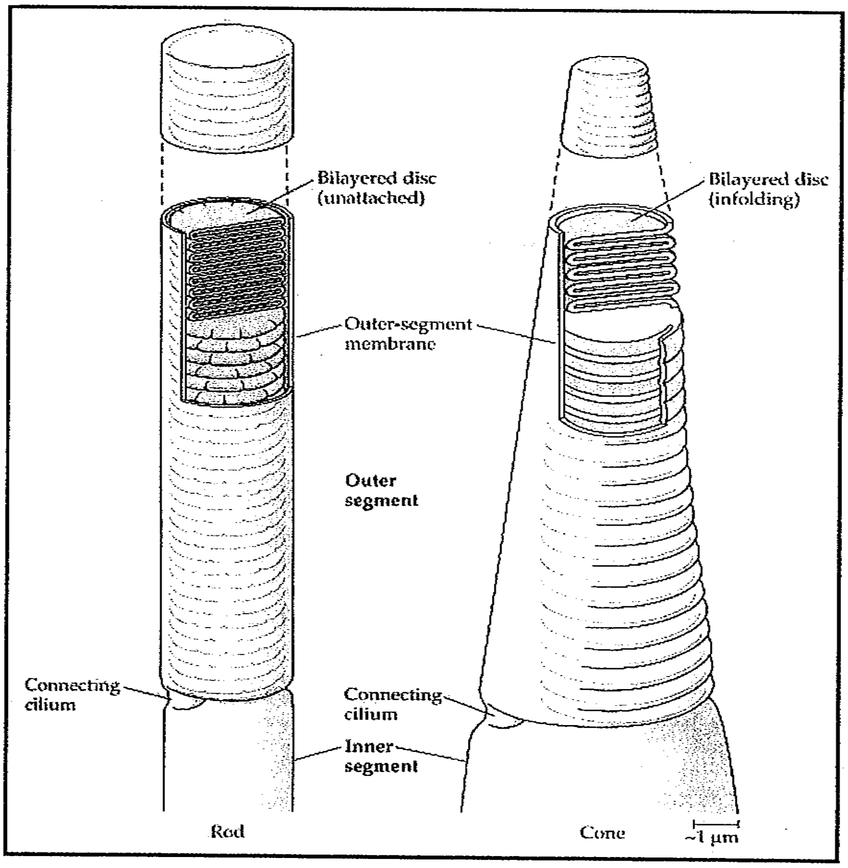
Sensory Retina

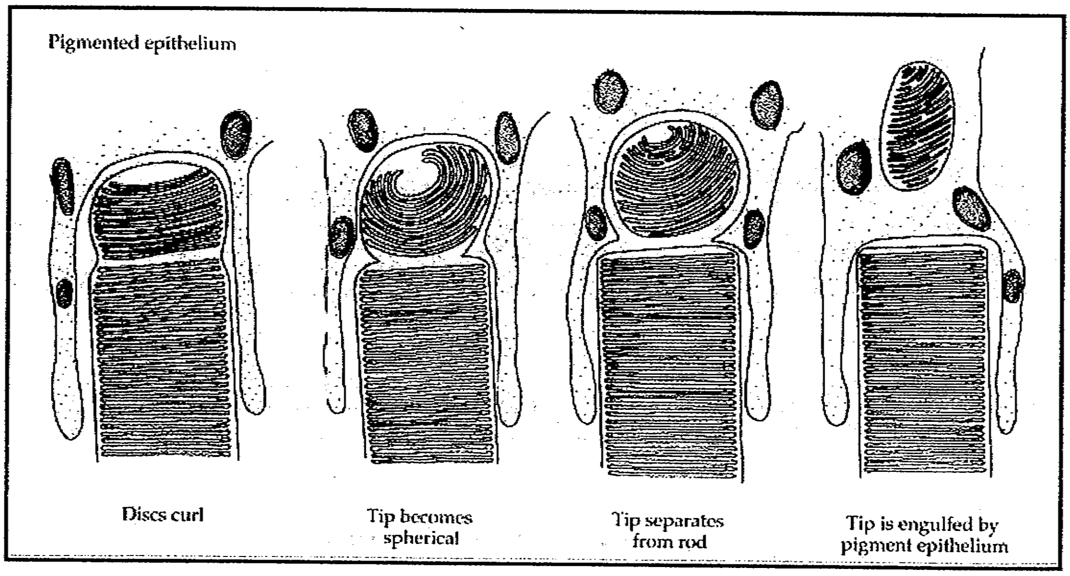
Rods and Cones

- **Number:** Rods = (**110 - 130** million) & Cones (**6.3 - 6.8** million)
- **Parts:**
  1) ***Outer segment:*** *surrounded by the interphoto-receptor matrix & the microvilli of RPE*
  2) ***Cilium:*** *a tubular structure that connects the outer to an inner segment;*
  3) ***Inner segment:*** *which consists an ellipsoid and a myoid portion;*
  4) ***Outter rod (or cone) fiber,*** *which connects the inner segment to the cell body;*
  5) ***Cell body,*** *which contains the nucleus; and*
  6) ***Inner rod (or cone) fiber,*** *which terminates in a specialized synaptic ending.*

Outer segment:

- consists of a dense vertical stack of 700 flattened sacs or discs.
- The outer segment is surrounded by a plasma membrane that is continuous with the discs of cones but separate from rod discs.
- Shape:
  - ***Rod*** outer segment have a cylindrical shape.
  - ***Cone*** outer segments have a conical shape.
    → In the foveal region the cones are ***more slender*** than elsewhere and resemble the cylindrical shape of rods.
    → Outside of the fovea centralis the tapered portion of the cone is short and the microvilli of the RPE are longer, to reach the cone outer fiber.
- The space within each sac is occupied by the ***visual pigments***.
  - ***Rods***: contain rhodopsin, a light-sensitive pigment.
  - ***Cones***: contain three different photopigments responsible for color vision.
- The extracellular fluid is the ***interphotoreceptor matrix***, which surrounds the microvilli of the apices of the RPE & the distal portions of the rod and cone outer segments. It is composed of a mixture of:
  - The ***proteoglycans*** and ***lysosomes*** originate in the RPE.
  - The ***interphotoreceptor retinoid-binding protein*** originates in the rods.
  - ***Detached photoreceptor discs.***
    → Antigenic (injection of minute amount into experimental animals excites a severe bilateral uveitis).
    → Engulfed by the microvilli and digested by intracellular lysosomes of the RPE.


Bilayered disc
(unattached)
Bilayered disc
(infolding)
Outer-segment
membrane
Outer
segment
Connecting
cilium
Connecting
cilium
Inner
segment
Rod
Cone
~1 μm


Pigmented epithelium
Discs curl
Tip becomes
spherical
Tip separates
from rod
Tip is engulfed by
pigment epithelium

Cilium:

- Connects the outer segment to the inner segment.
- It contains 9 pairs of ***microtubules*** but lacks the central pair seen in mobile cilia.
- This structure ***transmits cellular components*** from the inner segment and cell nucleus to the discs and their plasma membrane.

Inner segment: is divided into: (The division into ellipsoid and myoid portions is more distinct in rods than in cones)

- refractile outer **ellipsoid portion:** ⇒ Energy production.
  - Contains *mitochondria* grouped around the basal body of the cilium.
  - Na^+ K^+ pumps in this portion are active in visual transduction.
- nonrefractile basophilic inner **myoid portion:** ⇒ Synthesis.
  - Contains *ribosomes*, *Golgi complexes*, and a variety of *vesicles & vacuoles*.
  - There are refractile droplets of *coloured lipids* → act as light filters

Outer fiber:

- Length depends on the distance between the myoid and the cell body. Most outer fibers of ***cones*** are ***shorter*** than those of rods.
- Surrounded by the terminal bars (zonula adherens) of Muller cells. In light microscopy this is the ***external limiting membrane***. These bars provide a vertical orientation for the photoreceptors.

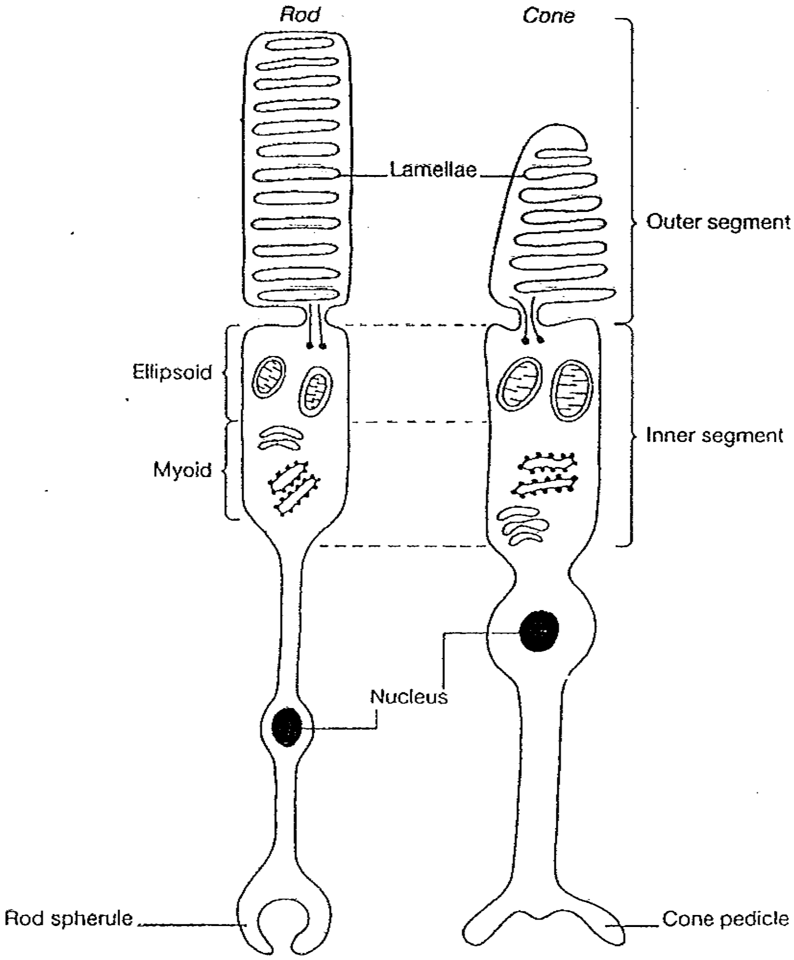
Cell body: **(rod & cone granule)**

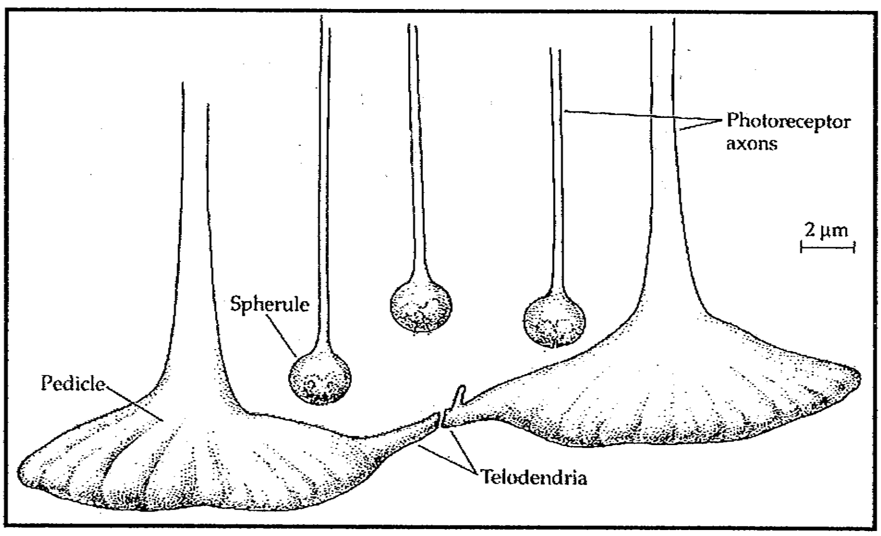
- Located in the outer nuclear layer.
- Consists almost entirely of ***nucleus***.

Inner fiber: (rod or cone inner fiber):

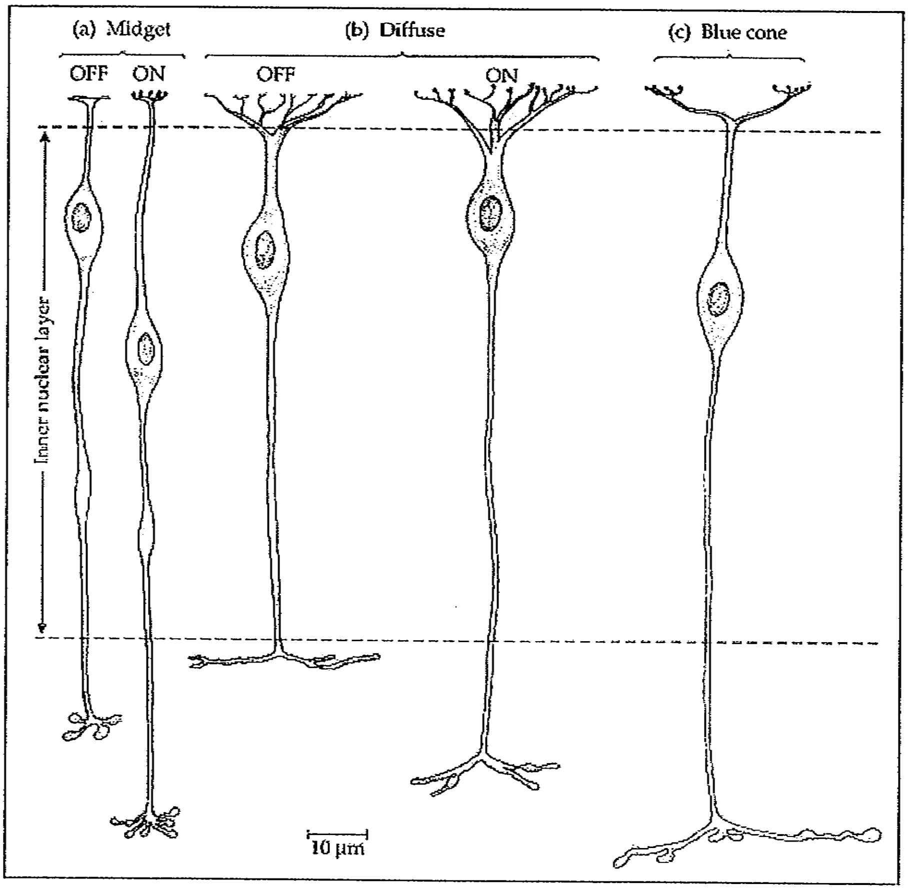
- Passes in the outer plexiform layer and terminates in a synaptic expansion [*rod spherule* or *cone pedicle* (conefoot)]
- These synapse in the outer plexiform layer with cells whose nuclei are in the inner nuclear layer. There are several types of synaptic endings. and it is possible that at this level the nerve impulse is both integrated and inhibited.

> - Mature visual cells ***do not replicate*** & their DNA is stable, in contrast, RNA (t-RNA. and m-RNA) are constantly renewed by the cell nucleus & passed to the myoid.
> - The organelles of the myoid synthesize the ***visual pigments***, the ***phospholipids***, ***proteins*** of the outer segments & the ***interphotoreceptor matrix***. Proteins reach outer segment through the connecting cilium.

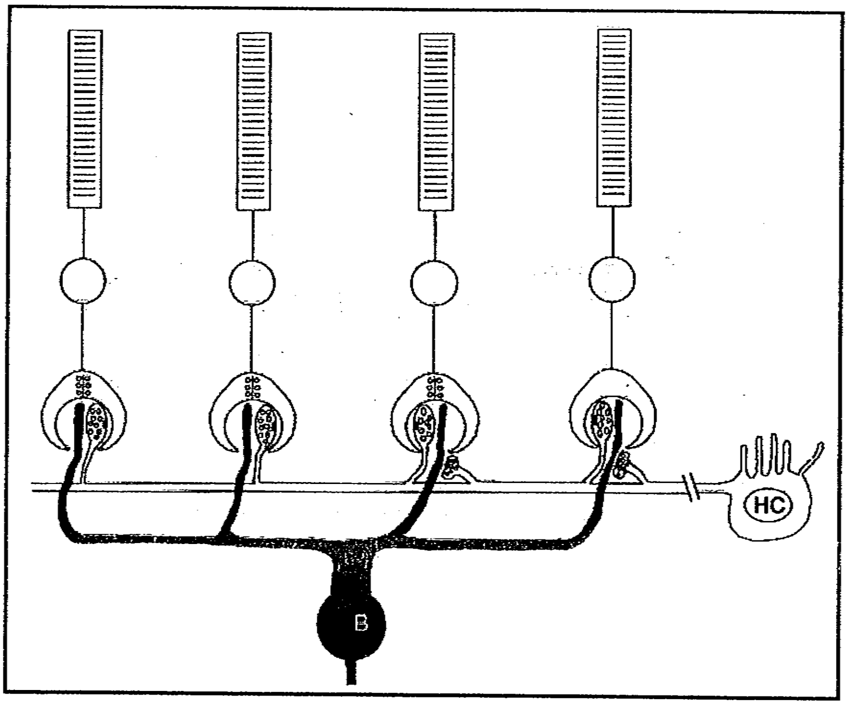

Rod
Cone
Lamellae
Outer segment
Ellipsoid
Myoid
Inner segment
Nucleus
Rod spherule
Cone pedicle


Photoreceptor axons
2 μm
Spherule
Pedicle
Telodendria

	Rods (40-20 μm)	**Cones** (80 μm at fovea) (40 μm at periphery)
Outer segment	• ***Cylindrical*** • Contains ***Rhodopsin*** • Surrounded by a plasma membrane that is ***separate*** from rod discs. = **Closed disc** • Tips are ***phagocytosed*** by RPE	• ***Conical*** + shorter than that of rod. • Contains ***Iodopsin*** (1000-1200 molecules) • Surrounded by a plasma membrane ***continuous*** with the cones discs. = **Open disc** • Tips are ***not phagocytosed*** by RPE
Cilium	• Connecting stalk *concentrically* placed.	• Connecting stalk *eccentrically* placed.
Inner segment		
Outer fiber (pass through **external limiting membrane**)	• ***Longer***	• ***Shorter*** (present only at the fovea) • Not present outside fovea.
Cell body In the **Outer nuclear layer**		
Inner fiber In the **Outer plexiform layer**	• terminates in a synaptic expansion → ***rod spherule***	• terminates in a synaptic expansion → ***cone pedicle*** (cone-foot)
Distribution	• Outside the rod-free area → the number of rods ↑ rapidly reaching maximum of about 160,000/mm^2 in a ring zone 5-6 mm from the fovea. • Peripheraly, the number of rods ↓ but remains higher than cones • More plentiful in the upper nasal retina.	• Fovea contains only cones 147,000/mm^2 • The number of cones ↓ from the center to the periphery, but ↑ again slightly at ora serrata
Number	• 110 - 135 million	• 6.3 - 6.8 millions
Staining Mallory's triple stain After Zenker fixation	• **Inner portion** ○ Outside macular region → ***Blue*** ○ Inside macular region → ***Red***	• **Inner portion → Red**



(a) Midget
OFF
ON
(b) Diffuse
OFF
ON
(c) Blue cone
Inner nuclear layer
10 μm



HC
B

Bipolar cells

(1st order neuron)

- Connections:
  - ***Dendrites*** attach to photoreceptor terminals with ***desmosomes***.
  - ***Terminal synapses:***
    - ***Synapse*** with horizontal cells.
    - ***Synapse*** with the dendrites of ganglion cells & the processes of amacrine cells, in the inner plexiform layer.
- Types:
  - **Midget** bipolar cells → connect ***single cone*** with a ***single midget ganglion*** cell
    - All cones synapse with at least one midget bipolar cell and often with other bipolar cells.
    - Midget bipolar cells generally synapse with a single cone & a single midget ganglion cell.
  - **Flat or diffuse** bipolar cells → connect ***many cones*** with ***many ganglion*** cells
  - **Rod** bipolar cells → connect ***many rods*** to ***1-4 ganglion*** cells.
  - **Interplexiform.**

Horizontal cells

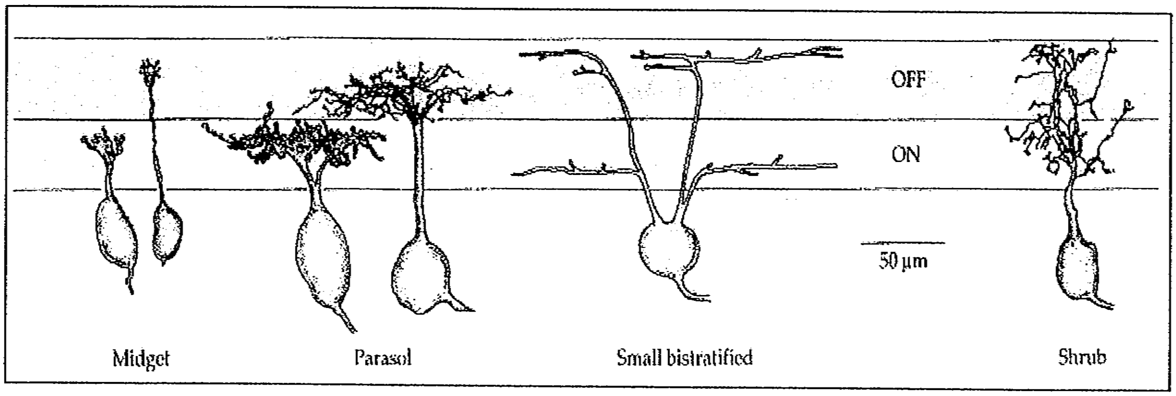
- Site:
  - *Cell* body contains nuclei are located in the outer portion of the inner nuclear layer.
  - Both their ***axons and dendrites*** are located in the outer plexiform layer.
- Shape: *Multipolar cells* with *one long process* & *several short processes* which run horisontally parallel to the surface of the retina
- Connections:
  - ***Short processes (dendrites)*:.**
    - synapse with several close ***photoreceptors*** (*7 cone pedicles* or *10-12 rod spherules)*
  - ***Long processes (Axons)*:**
    - synapse with several ***photoreceptors*** in a distant part of the retina.
    - synapse with ***bipolar cells***.
- Function:
  - ***Sharpening contrast and increase resolution*** by inhibiting the activity of bipolar cells (by liberating GABA in response to the neurotransmitter liberated by rods and cones following excitation by light)
  - ***Integrate visual stimuli***

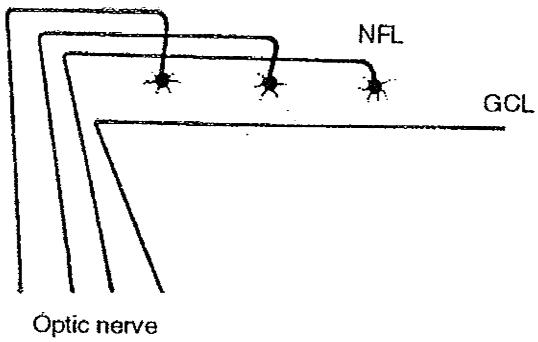
Amacrine cells

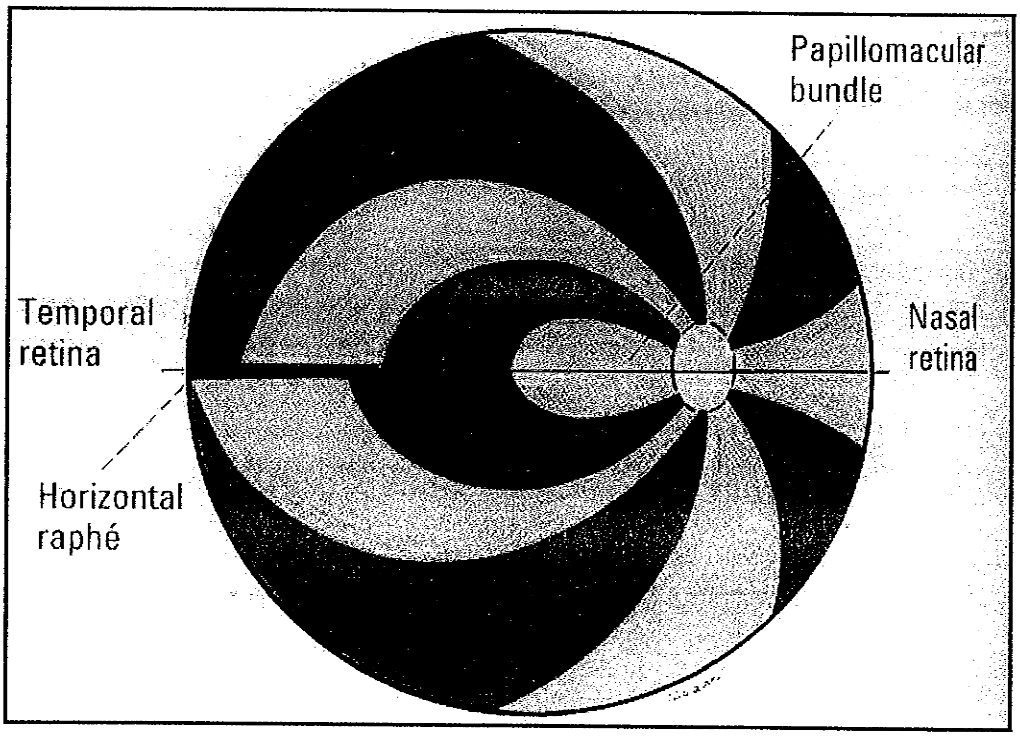
- Site:
  - ***Cell bodies*** lie at the inner portion of the inner nuclear layer,
  - ***Processes*** are directed inward towards the ganglion cell layer & located in the inner plexiform layer
  - Oriented against the direction of the transmission of the light impulse.
- Shape: **Pyrifiorm**
- Connections: Their ***cell processes*** synapse with
  - Dendrites of ***ganglion cells***.
  - Axons of ***bipolar cells***.
- Function : (they are stimulated by bipolar cells & inturn they excite ganglion cells)
  - **Temporal summation** (the long horizontal pathway ensures that laterally placed ganglion cells is stimulated)
  - **Modulate** signals from bipolar cells to ganglion cells.
  - **On/Off** response to light.

Muller cells

- Function: They are *large astrocytes* that ***mechanically support*** the retina.
- Parts:
  - ***Cell body*** contain nuclei located in the middle portion of the ***inner nuclear layer***.
  - ***Outer processes*** *Terminal bars* (zonula adherens) attach to the *outer fibers* of the photoreceptors forming → ***External limiting membrane***.
  - ***Inner processes*** *Foot plates* (Expanded terminations) covered by *Basement membrane* forms → ***Internal limiting membrane***.


OFF
ON
50 µm
Midget
Parasol
Small bistratified
Shrub


NFL
GCL
Optic nerve


Papillomacular bundle
Temporal retina
Nasal retina
Horizontal raphé

Ganglion cells

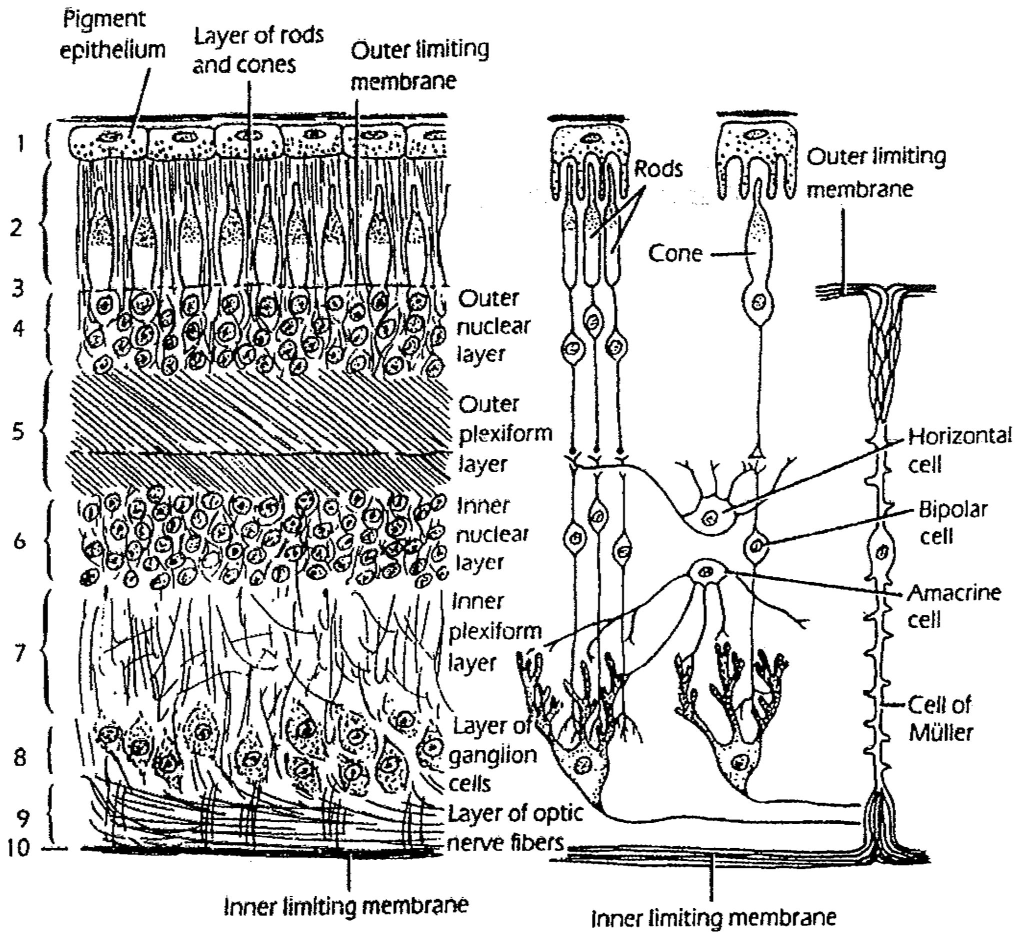
(2nd order neuron)

- Shape & types: *Multipolar* *10-30 μm* in diameter
  - Monosynaptic (midget) → Small + Central + linked by single midget bipolar cell to single cone.
  - Polysynaptic → Large + more peipheral + synapse with hundreds of bipolar cells ⇒ 4 types
    - Unstratified (most widely spread) o Diffuse o Diffuse large o Stratified diffuse

- Connections :
  - **Dendrites:** synapse with the axons of ***bipolar*** cells and ***amacrine*** cells in the inner plexiform layer.
  - **Axons:**
    - Axons transmitting visual impulses synapse in the ***laleral geniculate body***.
    - Axons transmitting afferent impulses that control the pupillary response to light synapse in the ***pretectal nuclei*** in the midbrain.

- **Ganglion cell layer:**
  - The inner most retinal layer that contain nuclei of ganglion cells.
  - Thickness:
    - In the ***retinal periphery***: the ganglion cell layer is a **single** cell thick
    - In the ***Parafoveal Region***: the ganglion cell layer is **5-10** layers thick.
    - In the **fovea**: the ganglion cell layer is **absent**.

- **Nerve fiber layer:**
  - Unmyelinated (transparent) axons of ganglion cells.
  - Arranged in *Bundles* *parallel* to the surface of the retina.
  - Thickness:
    - Thickest around the margin of the disc (20-30 μm)
    - Thickness differ with quadrant (from thickest → thinnest)
      ⇒ Uppe medial ⇒ lower medial ⇒ direct medial ⇒ upper lateral ⇒ lower lateral ⇒ Direct lateral
    - Papilloedema starts in the thickest part → thinner part.
  - Arrangement of axons in NFL:
    - ***Macular*** fibers (originating from ganglion cells of the Macula)
      → extend direct medially to the optic nerve. (papillo-macular bundle)
    - ***Temporal*** fibers (originating from ganglion cells temporal to the disc but not from macula)
      → arch above and below the macula but do not cross the horizontal raphe of the retina (which extends temporally from the fovea centralis to the ora serrata).
    - ***Nasal fibers*** (originating from ganglion cells nasal to the optic disc)
      → extend straight radialy towards the optic disc.
  - The major branches of the ***CRA & CRV*** are located in the NFL.


Pigment epithelium
Layer of rods and cones
Outer limiting membrane
1
2
3
4
5
6
7
8
9
10
Outer nuclear layer
Outer plexiform layer
Inner nuclear layer
Inner plexiform layer
Layer of ganglion cells
Layer of optic nerve fibers
Inner limiting membrane
Rods
Cone
Outer limiting membrane
Horizontal cell
Bipolar cell
Amacrine cell
Cell of Müller
Inner limiting membrane

Retinal layers

- *RPE*

- *Layer of rods and cones*

- *External limiting membrane*

- *Outer nuclear layer* → contains the nuclei of ***photoreceptors***.

  Rod granules
    - Consist of nucleus with very little cytoplasm around.
    - Arranged in 4 layers of nuclei

  Cone granules
    - Larger oval nuclei
    - Arranged as a single layer close to the Ext. Limiting membrane
    - Occasionally (in the foveal region) cone nuclei may be found on the outer side of the Ext. Limiting membrane, called → Extruded nuclei

- *Outer plexiform layer*
    - Synapses between
      - → ***rods spherules & cones pedicles*** and
      - → dendrites of ***bipolar*** cells & processes of ***horizontal*** cells.
    - Muller fibers

- *Inner nuclear layer*
    - The nuclei of
      - → ***Bipolar*** cells. (middle portion)
      - → ***horizontal*** cells. (outer portion)
      - → ***amacrine*** cells. (inner portion)
      - → ***Muller*** cells. (middle portion)
    - Capillaries of central retinal vessels.
    - Inter-plexiform cells → linking outer & inner plexiform layers.

- *Inner plexiform layer*
    - Synapses between
      - → ***bipolar*** cells → Axons
      - → ***ganglion*** cells → Dendrites
      - → ***amacrine*** cells → Processes
    - Muller fibers

- *Ganglion cell layer* → contains the nuclei of ***ganglion cells***.

- *Nerve fiber layer*
    - Axons of ganglion cells.
    - Retinal blood vessels
    - Muller fibers
    - Centrifugal fibers
    - Glial cells (form meshwork around the vessels)

- *Internal limiting membrane*

♣ External limiting membrane:

- **Definition:** widely fenestrated membrane extending from the edges of the optic disc to the ora serrata (where it becomes continuous with the cement substance between pigmented and non pigmented ciliary epithelium)
- **Structure:**
  - → A membrane with holes through which cones and rods pass
  - → The diameter of aperture depends on structure that will pass through it, thus:
    - ⇒ The outer fibers of rods have small aperture
    - ⇒ The inner segment of cones have larger aperture
    - ⇒ At the fovea (where cones are exceptionally fine) → holes are smaller.
- **Ultra structure:** → It consists of junctions known as ***terminal bars*** between the cell membranes of the *outer fibers* of the rods & cones & *outer processes* of Muller cells
- **N.B.** in the fovea → the greater length of cones pushes the External Limiting membrane forward → posterior concavity called **The Fovea Externa**

♣ Internal limiting membrane:

- Formed of →
  - Outer layer (True ILM) → *Foot plates* (expanded terminals) of the inner processes of Muller cells
  - Inner layer → *basement memb*. (posterior hyaloid membrane of the vitereous)
- The membrane is absent in
  - Between the disc and the vitreous
  - At sites where large blood vessels come close to the hyaloid
- Relations
  - Outer surface → irregular & facing NFL.
  - Inner surface → smooth & facing vitreous.

> **Posterior Hyaloid membrane (in PVD)** is a part of the ILM (Both are Type IV collagen)
> Not a condensation of the peripheral vitreous cortex (Type II collagen)

Attachment of the retina

- The neural retina is firmly attached to the underlying RPE at
  - Margins of the optic disc.
  - Ora serrata.

Thickness of the retina

- Optic disc → 560 µm
- Around the macula → 350 µm
- Equator → 180 µm
- Ora serrata → 100 µm
- Fovea → 90 µm

Regions of the Retina

Ora serrata: (0.1 mm thickness)

- The scalloped anterior termination of the sensory retina adjacent to the pars plana.
- Located about 8.5 mm from the corneoscleral limbus. (extends nasal & above more than temporal & below).
- In this area the sensory retina abruptly loses its laminated structure & the two layers of the primitive optic vesicle fuse & continue forward as the ciliary epithelium (pars ciliaris retinae)

Central retina (macula lutea): (0.56 mm thickness near the optic disc)

- Extends from the fovea centrails
  - nasally almost to the optic disc,
  - About the same distance temporally, above and below the fovea.
- This region is about 5 mm in diameter.
- In this region
  - Ganglion cell layer has more than one layer of nuclei.
  - Retinal layers from the outer nuclear layer inward have a ***yellow carotenoid pigment*** *(xanthophyll)* → Macula lutea = yellow spot
- *The fovea centralis*
  - A depressed area located in the central retina about **3** mm (2 disc diameters) temporal to the optic disc and **0.8** mm below the horizontal meridian.
  - Diameter = **1.5** mm.
  - The sides of the depression form the ***clivus***.
  - Its center of the depression forms the ***foveola*** (thinnest area of the retina)
    - → measures about 0.4mm in diameter.
    - → The photoreceptors in the fovea centralis are ***only cones***. (The outer segments of cones in the foveola are densely packed, thin, long, and attenuated.)
    - → The foveola is nurtured solely by the ***choriocapillaris*** and does not contain the capillaries of the sensory retina.
    - → The inner cell layers are displaced peripherally, and only the layers of
      - ⇒ *cones*,
      - ⇒ their nuclei in the *outer nuclear layer*, and
      - ⇒ their connections in the *outer plexiform layer* are present.

Peripheral retina:

- The **photoreceptors** are
  - mainly rods
  - few cones (with outer segments thicker than those in the central retina)
- The **outer plexirorm layer** is vertically arranged.
- The **inner nuclear layer** has a regular orientation.
- The **ganglion cells** are larger (polysynaptic) than those in the central retina, and their cell bodies are aranged in a single layer.

⇒ ***Functionally***, the retina is divided into temporal and nasal portions by a line drawn vertically through the center of the **fovea**. Light impulses originating from cells temporal to this line pass to the lateral geniculate body on the same side. Light impulses originating from cells nasal to this line cross in the optic chiasma to the opposite side of the brain.

⇒ ***Ophthalmoscopically***, the clinician uses the **optic nerve** to divide the retina into superior and inferior temporal portions, superior and inferior nasal portions, and a central area. The different quadrants are further divided into the regions posterior and anterior to the equator.

Ora Serrata

- **Definition:** The scalloped anterior termination of the sensory retina adjacent to the pars plana

- **Gross Anatomy**

  - **Site**
    - **8.5** mm → from the limbus
      (nasally it is 1mm closer to the root of the iris than temporally)
    - **6** mm → from the equator.
    - **25** mm → from the optic nerve.

  - **Shape:**
    - ***Dentate processes*** (best marked on the nasal & upper)
    - At the ora serrata
      - → ***Retina*** is firmly adherent to the ***Choroid***.
      - → ***Retina*** is firmly adherent to the ***Vitreous***.
      - → ***Sensory retina*** is firmly adherent to ***RPE***.

  - **Thickness ⇒ 100 µm**

- **Histological changes:** On approaching the ora serrata the following occur

  - *RPE* → Large + Irregular + Variable amounts of melanin

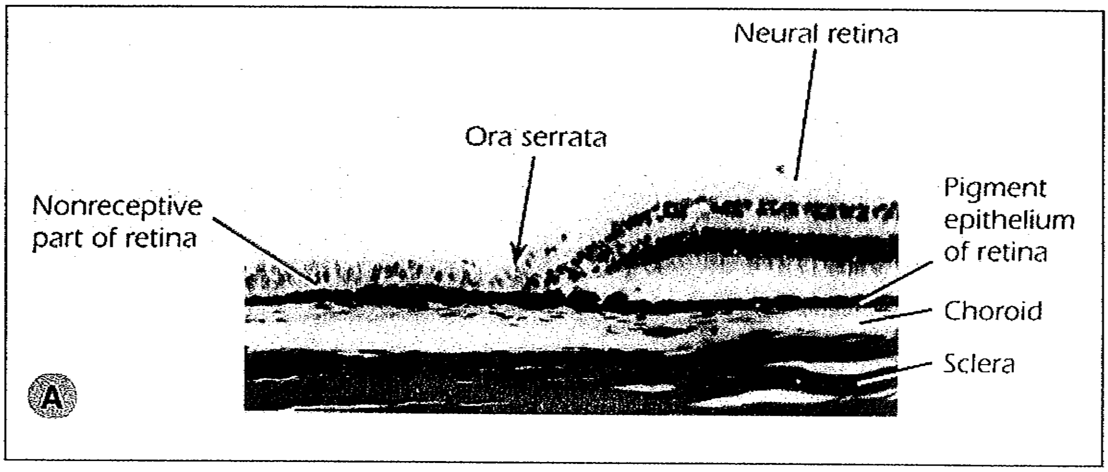
  - *Photoreceptors*
    - Rods ⇒ Number ↓ and disappear first (4mm)
    - Cones ⇒ Malformed & disappear (2mm)

  - *Nuclear layers* ⇒ Thinner and Fuse

  - *Ganglion cells* ⇒ become sparse, invade NFL & both end 0.5-1 mm from the ora.

  - *External limiting membrane* ⇒ continues ***between*** the layers of ciliary epithelium

  - *Internal limiting membrane* ⇒ continues ***over*** the ciliary epithelium ⇒
    (B.M of non pigmented ciliary epithelium)


Neural retina
Ora serrata
Nonreceptive part of retina
Pigment epithelium of retina
Choroid
Sclera
A

Macula Lutea

Definition:

- An *oval ill-defined* area of yellowish coloration within the central retina.
- Corresponds to 15° of visual field
- Adapted for ***accurate*** diurnal vision & ***color*** discrimination

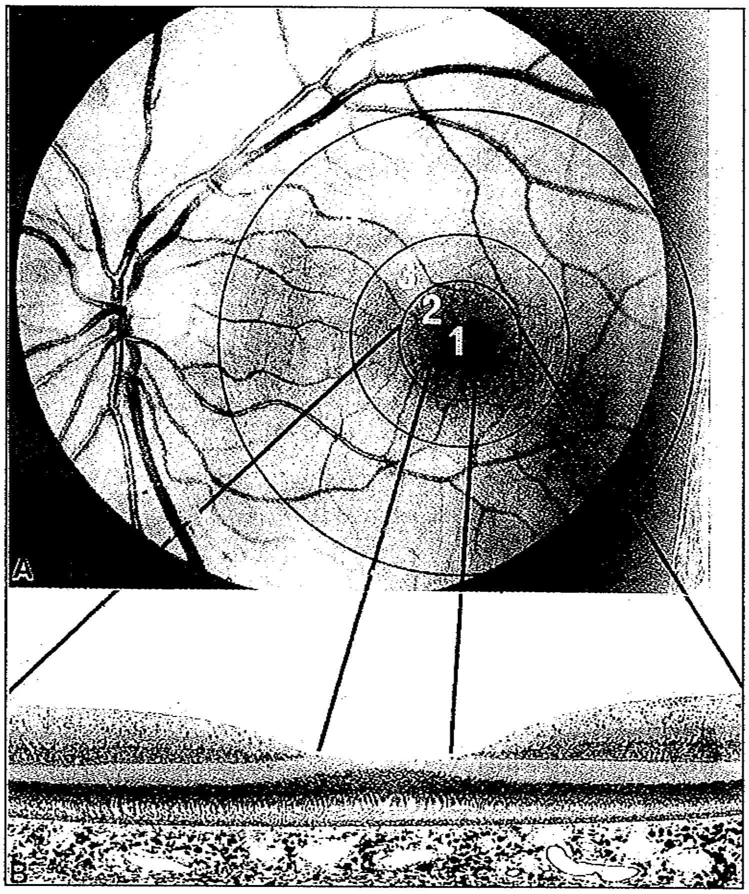
Gross Anatomy:

- **Site**
    - Within the temporal arcades.
    - Its center →
        - ⇒ **3 mm** temporal to optic disc edge
        - ⇒ **1 mm** below optic disc center (horizontal meridian)
- **Size** → **5.5 mm** in diameter.
- **Shape** → *Horizontally oval, ill-defined, shallow*
- **Colour**
    - By OPHTHALMOSCOPY: → Not easily identified
    - Ophthalmoscopy with RED FREE LIGHT:
        - ⇒ Macula → Greenish yellow darker than surrounding
        - ⇒ Fovea → yellow brown, surrounded by oval hallow light reflex.
    - Fresh ENUCLEATED eye:
        - ⇒ Macula → yellowish
        - ⇒ fovea → colorless
- **Thickness**
    - Macula → **350** μm
    - Fovea → **90** μm

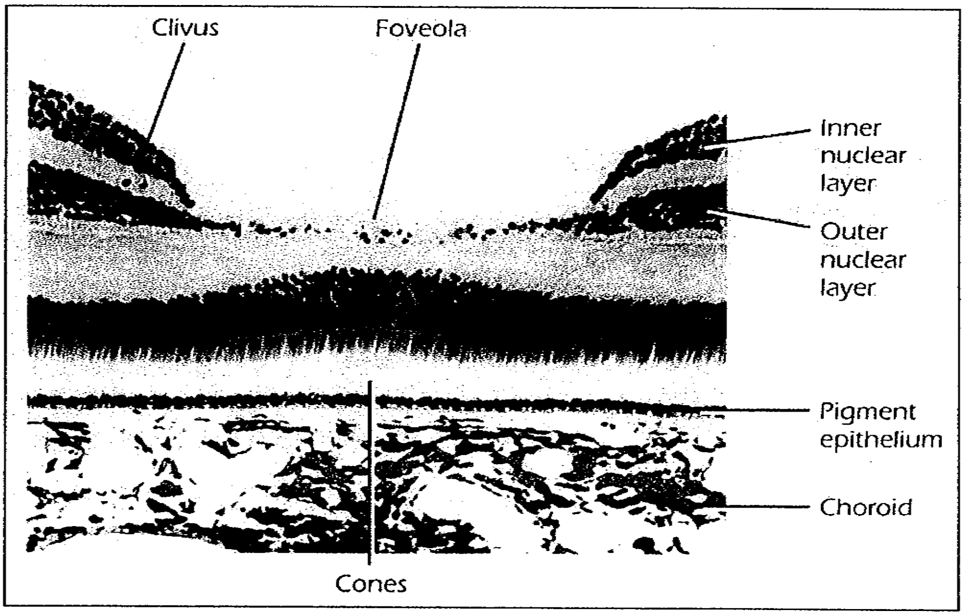
Subdivision of the macula:

- ***Fovea*** (clinical macula)
    - Central depression within the macula.
    - **1.5** mm in diameter → **5°** of visual field.
- ***Foveola*** (clinical fovea)
    - Central concave indentation within the fovea.
    - **0.35** mm in diameter → **1°** of visual field.
    - Appears deeper red in color than does the adjacent retina *because of rich choroidal circulation which shines through it*
- ***Umbo*** → center of fovea
- ***Para-foveal*** region → **0.5** mm in diameter
- ***Peri-foveal*** region → **1.5** mm in diameter

♣ *Clivus* → the downward sloping foveal border that meets the floor of the foveola
♣ *FAZ* (foveal avascular zone) → area within the fovea devoid of blood capillaries.



A
2
1
B



Clivus
Foveola
Inner nuclear layer
Outer nuclear layer
Pigment epithelium
Choroid
Cones

Histological changes:

At the MACULA:

1) **Choriocapillaris** ⇒ capillaries are → denser, wider with larger fenestrae → better nutrition of central cones.

2) **Retina** ⇒ The 10 layers of retina could be identified

- **RPE**
  - It is the layer of the polygonal cells firmly attached to Bruch's membrane.
  - Structure of the cells (see diagram).
  - In the macula → RPE gets
    - → Taller. 11-14 µm
    - → Narrower. 9-11 µm
    - → Darker.
    - → Denser.

- **Photoreceptors**
  - They are the end organs of dendrites of a nerve cell.
  - Structure of rods and cones (see diagram).
  - In the macula:
    - ⇒ Only cones are present at the fovea and foveola:
      - → ***Highest density*** within the retina → 147.000/mm^2
      - → Cones are ***densely packed***, ***thinner***, ***taller*** → 80 µm
    - ⇒ Rods are present at the most periphery.

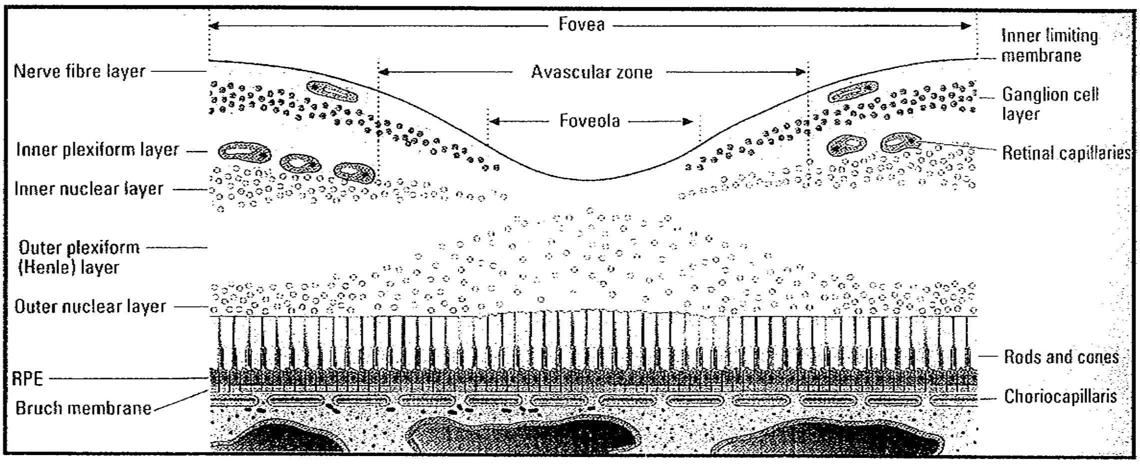
- **External limiting membrane**
  - The *holes* are smaller as inner segment of cones are exceptionally thin.
  - ***Fovea externa***: the greater length of the cones push ELM forwards.

- **Outer Nuclear layer**
  - Nuclei of cones and rods.
  - Nuclei of cones may be found on the outer side of ELM → ***extruded nuclei***

- **Outer plexiform layer**
  - Synaptic junction between cones, rods and bipolar cells & horizontal cells.

- **Inner nuclear layer**
  - Contains the nuclei of
    - → *Bipolar* (Here, ***midget bipolar*** cells are seen in the fovea)
    - → *Horizontal*,
    - → *Amacrine* and
    - → *Muller* cells.

- **Inner plexiform layer**
  - Contains
    - Synapses between
      → ***bipolar*** (Axons) → ***ganglion*** (Dendrites) → ***amacrine*** (Processes)
    - Muller fibers


Fovea
Inner limiting membrane
Nerve fibre layer
Avascular zone
Ganglion cell layer
Foveola
Inner plexiform layer
Retinal capillaries
Inner nuclear layer
Outer plexiform (Henle) layer
Outer nuclear layer
Rods and cones
RPE
Bruch membrane
Choriocapillaris

- **Ganglion cell layer**
  - Ganglion cells are 2nd order neuron of the visual pathway.
  - Here
    - → Contain ***yellow carotenoid pigment (xanthophylls)*** → Macula lutea = yellow spot.
    - → Arranged into 2 or more layer except at the fovea where they are absent.
- **Nerve fiber layer**
  - Consists of the ***papillo-macular bundle***.
  - Temporal fibers don't pass through the macula.
- **Internal limiting membrane**
  - ***Thickest*** than elsewhere.

■ At the FOVEA:

3 layers only:
- RPE.
- Cones (80 μm)
- Membranes (ILM - ELM)

Thinning is not due to actual reduction, but due to displacement of bipolar & ganglion cells peripherally.

■ The Sloping Retina (350 μm at the macula → 90 μm at the fovea)
- It is due to **Displacement of bipolar and ganglion cells** peripherally.
- ***Henle's layer***: it is an *outer plexiform layer* formed by the horizontally or obliquely running *inner fibers* of photoreceptors (⇒ macular star with exudation)

■ The PARA-FOVEAL zone:
- The region of ***greatest accumulation of bipolar & ganglion cells*** in the retina.

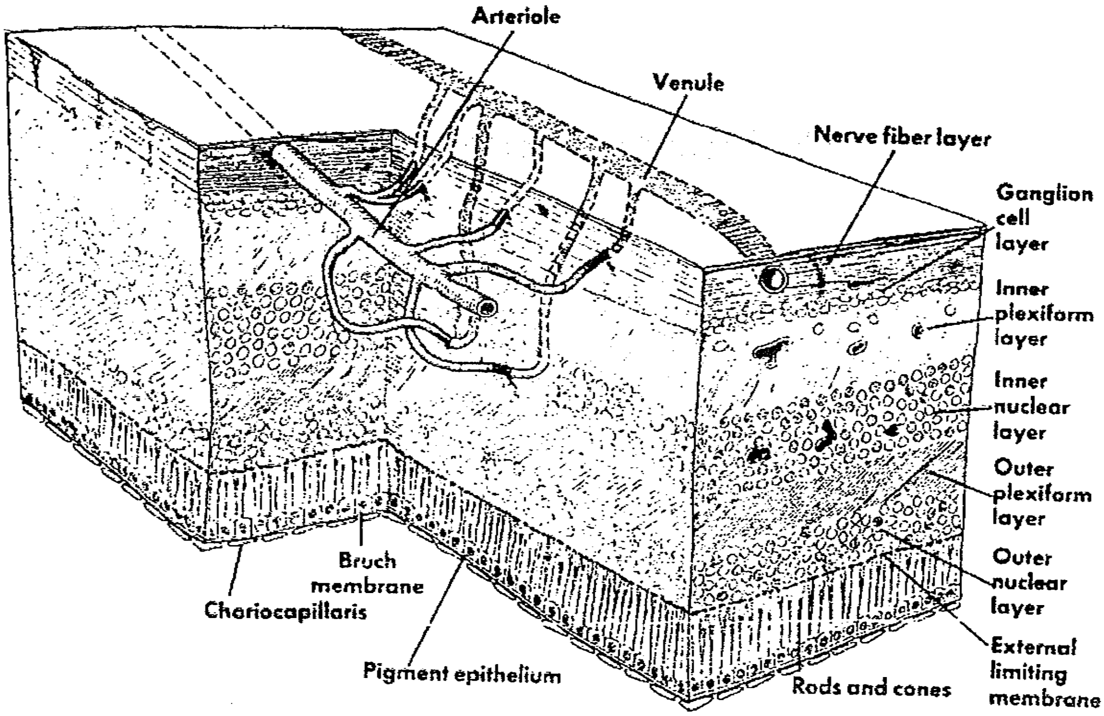
■ The PERI-FOVEAL zone:
- The density of cones is markedly reduced.
- Outer plexiform layer change from Henley layer to regular arrangement.

Blood supply:

- Central retinal artery through → twigs from the **temporal arcades.**
- **Ciliary circulation through → Cilio-retinal artery** in 20% of eyes.

Fovea is **avascular** and supplied by **diffusion from choriocapillaris**

N.B. The Macula is 1/20 of the retina, but its fibers form
- 1/3 of **optic nerve** fibers
- Most of **chiasma.**
- 1/3 **visual cortex**


Arteriole
Venule
Nerve fiber layer
Ganglion cell layer
Inner plexiform layer
Inner nuclear layer
Outer plexiform layer
Outer nuclear layer
External limiting membrane
Rods and cones
Pigment epithelium
Bruch membrane
Choriocapillaris

Blood supply of the Retina

Arterial:

1) Outer portion (1/3 = till OPL) is nurtured mainly by the ***choriocapillaris*** of the choroid.
2) Inner portion (2/3) is nurtured mainly by branches of the ***central retinal artery***.

> The border is the basket-like configuration of bipolar cell dendrites at the junction of the outer and middle thirds of the outer plexiform layer.

- The ***central retinal artery:*** (luminal diameter = 0.2 mm)
  - The first branch of the ophthalmic artery.
  - Enters the inferior medial side of the optic nerve about **12** mm posterior to the globe.
  - It extends forward to the optic disc, where it bifurcates into superior and inferior papillary branches.
  - As the vessel passes through the lamina cribrosa, its wall is reduced to about half its previous thickness, the internal elastic lamella is lost, and the medial muscle coat becomes incomplete. Thus its major branches within the eye are arterioles and not arteries.

> **Structure**
> **Intima** → *Endothelium* (nuclei projecting into the lumen) + *Subendothelial* loose C.T + *Internal Elastic lamina*
> **Media** → *Smooth muscle fibers* (centrally arranged) + *External Elastic lamina*
> **Adventitia** → *Collagenous & elastic fibers* (circularly & longitudinally arranged)

- The ***superior and inferior papillary branches*** of the central retinal artery bifurcate within the optic nerve or on the surface of the optic disc to form nasal and temporal branches. The **nasal** branches follow a relatively direct course to the periphery The **temporal** vessels arch above and below the fovea centralis and pass to the periphery.

> **Structure** → No I.E.L + Incomplete muscle

- *Capillaries*
  - Distributed in:
    - superficial network at the level of the **nerve fiber layer.** (present alone peripherally)
      - ⇨ Arterial abnormalities (such as vascular hypertension) tend to involve these capillaries.
    - intraretinal network at the level of the **inner nuclear layer.**
      - ⇨ The intraretinal capillaries receive blood from the capillaries in the nerve fiber layer.
      - ⇨ Venous abnormalities (such as diabetes mellitus) tend to involve these capillaries.

> N.B At the macular region → a 3rd capillary network is present.
> Around optic disc → 4 capillary networks are present. (in the superficial part of NFL & INL)
> Peripherally → only superficial network is present
> peripheral 1-1.5 mm at ora serrata → is avascular

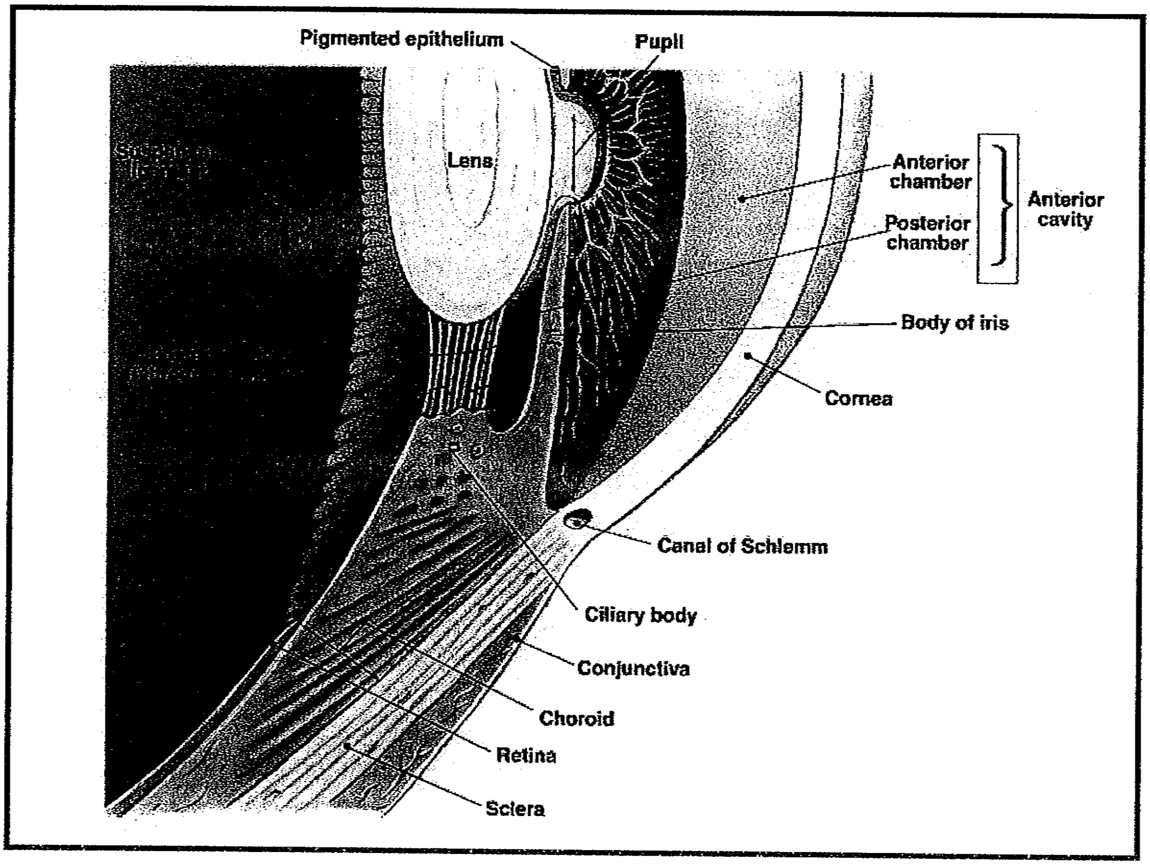
- The arterioles have a **capillary-free zone** surrounding them.
- The venous precapillaries have **capillary-dense area** surrounding them → compansation for the low oxygen tension in the venous side.

  - Structure:
    - The **endothelial cells** that line retinal capillaries are:
      - ⇨ ***Regularly arranged*** with their nuclei parallel to the direction of the vessel.
      - ⇨ ***Joined by terminal bars*** & forming together with the tight junctions of RPE the BRB
    - The vessel wall contains **pericytes** (mural cells) that are separated from the endothelium by its basement membrane

Veins:

- They follow the distribution of the arteries. (Diameter of the artery is 2/3 that of vein)
- **Formation** : by union of superior & inferior retinal veins in the lamina cribrosa.
- **Course** :
  - In the optic nerve it lies lateral to the artery
  - CRV exits from the optic n. about 12 mm behind the globe. (but proximal to the a.)

  Increased CSF pressure is transmitted to CRV as it crosses the subarachnoid space ⇒ Papilloedema
- **Ends** : in the cavernous sinus or superior ophthalmic vein or inferior ophthalmic vein (rare)
- **Branches** :
  - Communicating branch with the ***Superior ophthalmic vein***.
  - ***Posterior central vein of Kuhnt***. ⇒ passes backward in the center of the optic n.
- **Structure** :
  - They consist of an endothelial coat supported by a small amount of connective tissue.
  - At points in the retina where arteries cross veins, the vessels are bound together with a common adventitial sheath.
  - No *Internal elastic lamina* + No *External elastic lamina*


Pigmented epithelium
Pupil
Lens
Anterior chamber
Posterior chamber
Anterior cavity
Body of iris
Cornea
Canal of Schlemm
Ciliary body
Conjunctiva
Choroid
Retina
Sclera

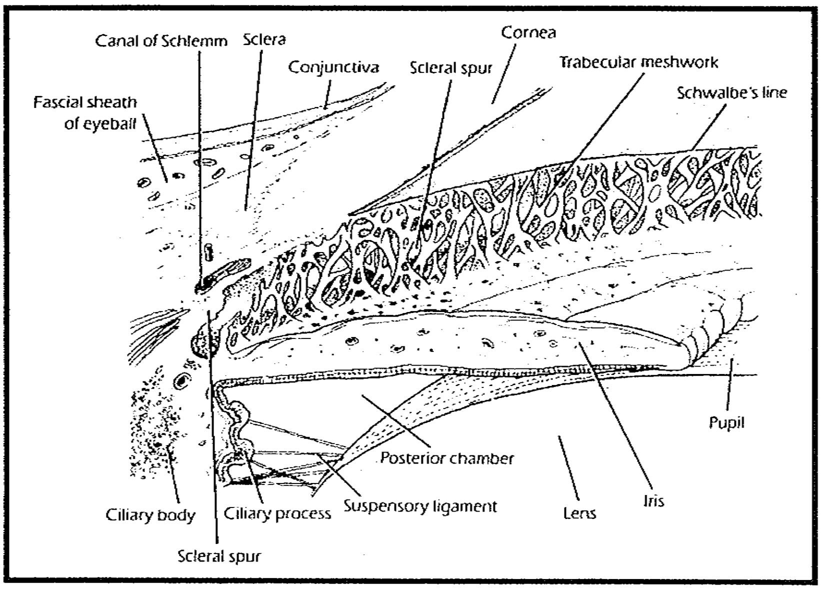
Chambers of the eye

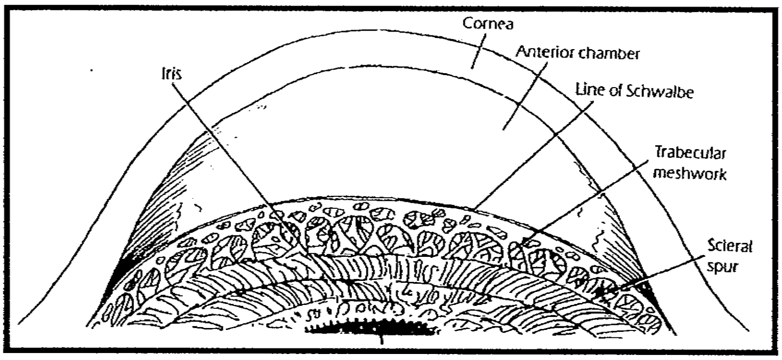
Anterior chamber

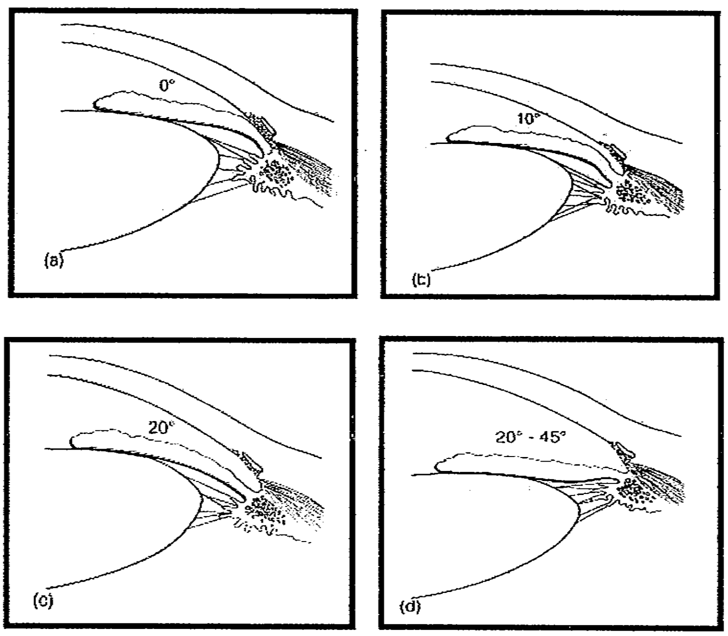
- **Bounded:**
  - anteriorly by the **cornea & trabecular meshwork** (peripherally)
  - posteriorly by the front surface of the **iris** and **lens**.
  - peripherally by the anterior chamber angle.
- **Volume:** approximately **0.2** mL.
- **Depth:** deepest in its central portion (3mm) and shallowest at the peripheral iris insertion. (NB. It is slightly shallower in ♀ ⇒ ACG is more common)

Posterior chamber

- **Bounded:**
  - anteriorly by the iris.
  - posteriorly by the anterior lens capsule and its zonule.
  - peripherally by the ciliary processes.
- **Volume:** in adults is about **0.06** mL.
- Aqueous humor is secreted by the nonpigmented epithelium of the ciliary processes into the posterior chamber and flows through the pupil into the anterior chamber.


Canal of Schlemm
Sclera
Cornea
Conjunctiva
Scleral spur
Trabecular meshwork
Schwalbe's line
Fascial sheath of eyeball
Pupil
Posterior chamber
Ciliary body
Ciliary process
Suspensory ligament
Lens
Iris
Scleral spur


Cornea
Anterior chamber
Iris
Line of Schwalbe
Trabecular meshwork
Scleral spur


0°
(a)
10°
(b)
20°
(c)
20° - 45°
(d)

Anterior chamber angle

Features :

(1) Anterior Shwalbe line
- The most anterior structure
- Represents peripheral termination of DM
- Marks the begining of TM

(2) Trabecular meshwork
- Extends from Shwalbe's line to scleral spur
- Gonioscopy → **ground glass appearance**
- Structure: ....

(3) Schlemm's canal
- An oval channel that encircles the entire circumference of the ant. Chamber
- Can be seen by gonioscopy
  - As a **dark line** in eyes without trabecular pigmentation
  - If goniolens press the episcleral veins → blood can be seen inside it

(4) Scleral spur
- The most anterior projection of the sclera
- The most important gonioscopic landmark
- Gonioscopically ⇒ dense narrow **whitish** band just posterior to the TM
- Receives insertion of **long. fibers of ciliary ms**
- Structure
  - Collagen & elastic tissue
  - Scleral spur cells (myofibroblastic cells)

(5) Ciliary body
- Just behind the scleral spur
- Its width depends on iris root insertion
- Wider in myopes

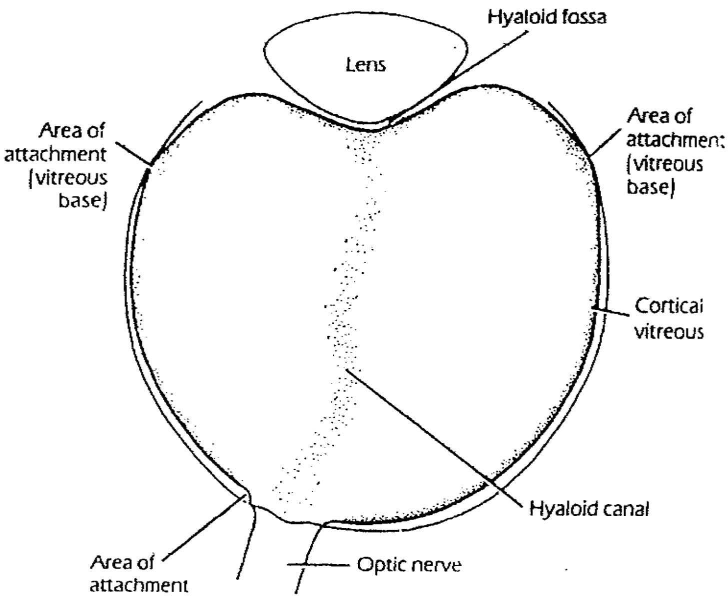
(6) Iris processes
- Extensions from the anterior surface of iris which inserts at level of scleral spur covering ciliary body
- Present in ⅓ eyes
- More prominent in children with brown eyes.

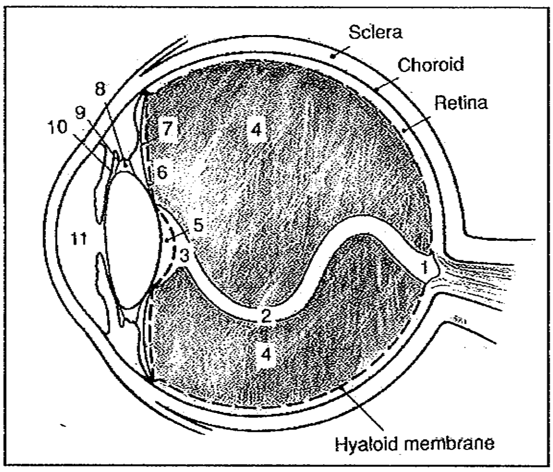
Angle Recess :
- The apex of the angle lies 0.6 – 1 mm behind the most anterior aspect of the lens.
- Therefore the iris curves backwards as it inserts in the ciliary body forming the recess.

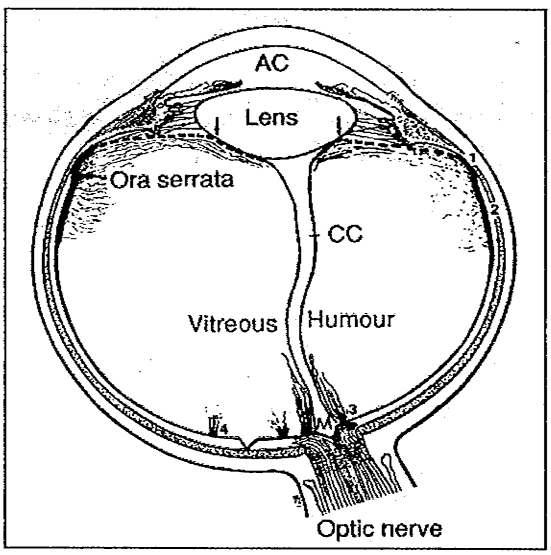
Gonioscopy :
- Light rays emerging from angle structures undergo TIR → Goniolens must be used to examine.
- Angle gradding by gonioscopy (Shatter)
  - G_4 → Widest ⇒ ***Ciliary body*** is seen (Myopes & aphakes)
  - G_3 → Wide ⇒ ***Scleral spur*** is seen
  - G_2 → Moderately narrow ⇒ ***Trabecular meshwork*** is seen
  - G_1 → Very narrow ⇒ ***Shwalbe's line*** is seen
  - G_0 → Closed ⇒ ***Iridocorneal touch***

Nerve supply of outflow apertures :
- Club shaped nerve endings with mechanoreceptor charachteristics
- Derived from supraciliary & ciliary nerve plexus in the scleral spur

Diagram of Different angle structures :


Hyaloid fossa
Lens
Area of attachment (vitreous base)
Area of attachmen: (vitreous base)
Cortical vitreous
Hyaloid canal
Area of attachment
Optic nerve


Sclera
Choroid
Retina
8
9
10
7
4
6
5
11
3
1
2
4
Hyaloid membrane


AC
Lens
Ora serrata
CC
Vitreous
Humour
1
2
3
4
Optic nerve

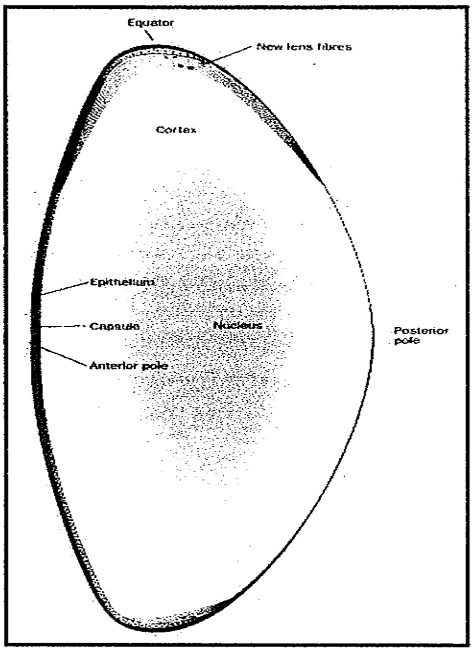
Vitreous Cavity

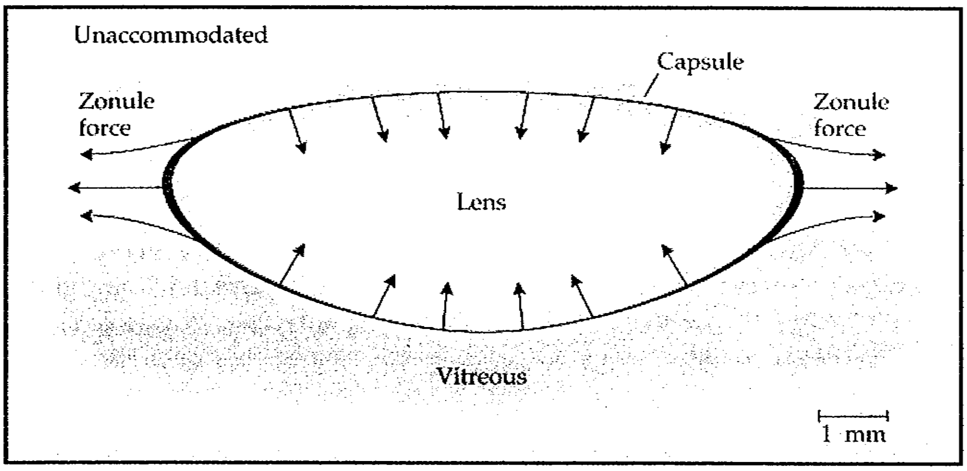
- **Bounded:**
  - anteriorly by the lens zonule, and ciliary body.
  - posteriorly by the retina and optic nerve.
- **Volume :** 4.5 mL.

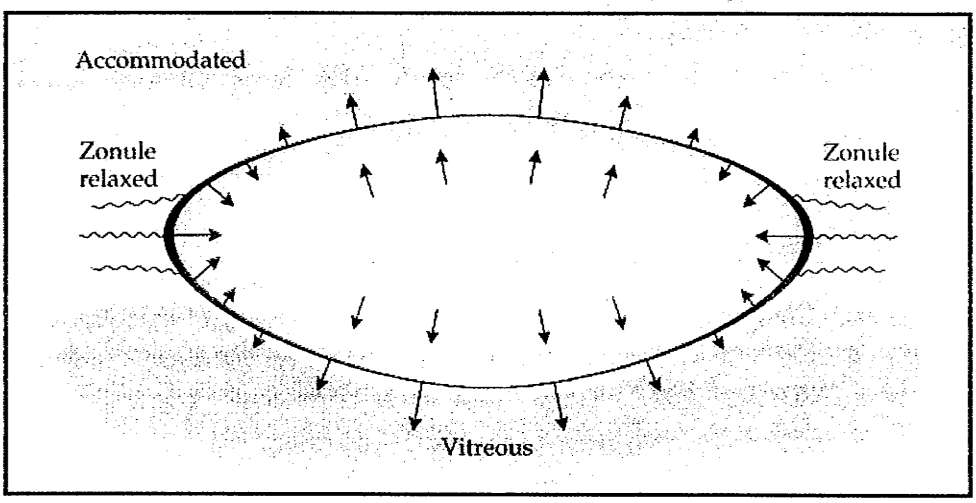
Vitreous Body

- **Definition:** A transparent gel that fills the posterior $^4/_5$ of the globe
- **Shape:** sphere with a saucer-shaped depression anteriorly for the lens (anterior hyaloid, lenticular fossa). In the region of the depression, the vitreous humor is condensed and is described clinically as the ***anterior hyaloid face***.
- **The vitreous attachment:**
  - Normally ***cortical vitreous*** *is loosely attached to* ***the internal limiting membrane*** of the retina by scattered ***collagenous filaments***, If the vitreous humor degenerates and collapses (vitreous detachment) → the filamentary attachments may adhere to the sensory retina → retinal hole → retinal detachment.
  - Sites of normal ***vitreoretinal*** adhesions:
    1) At the vitreous base: **4 mm band** of vitreous that overlies both the ora serrata and the pars plana ciliaris, to which it is attached by many fibrils ⇒ Very strong
    2) At the margin of the optic disc. ⇒ Fairly strong
    3) Around the fovea ⇒ Weak
    4) Around peripheral retinal blood vessels. ⇒ Weak
  - ***Vitreolenticular*** attachment The peripheral anterior hyaloid may be loosely attached to the posterior capsule of the lens → forming a circle of adhesion 9 mm in diameter (Weigert hyaloideocapsular ligament) → This adhesion is only firm in young then weakens by age ⇨ ICCE is easy in old.
- **Structure:**

  composed of a random network of uniformly thin ***collagen fibrils*** suspended in a highly dilute ***solution*** of salts, protein & hyaluronic acid. Its main component is water (98.5% - 99.3%).
  - ⇨ In **young** adults it is about 80% gel & 20% liquid vitreous humor that contains hyaluronic acid but not fibrils,
  - ⇨ With **aging**, the volume of liquid vitreous humor increases to about 50%.
- **Portions:**
  1) ***Cortical portion.***
     - Circumscribes the entire vitreous body adjacent to the lens & retina
     - Condensation of collagen fibrils, cells, proteins & mucopolysaccaride.
     - Cells ⇒ hyalocytes (stellate with darkly stained nuclei) (phagocytes)
  2) ***Central portion*** less dense with fewer fibrils than cortical vitreous.
- **Embryologically:** the vitreous is divided into three parts:
  1) Primary (mesenchymal, canal of Cloquet)
  2) Secondary (most of the adult vitreous)
  3) Tertiary (the lens zonule).


Equator
New lens fibres
Cortex
Epithelium
Capsule
Nucleus
Anterior pole
Posterior pole


Unaccommodated
Capsule
Zonule force
Zonule force
Lens
Vitreous
1 mm


Accommodated
Zonule relaxed
Zonule relaxed
Vitreous

The Crystalline Lens

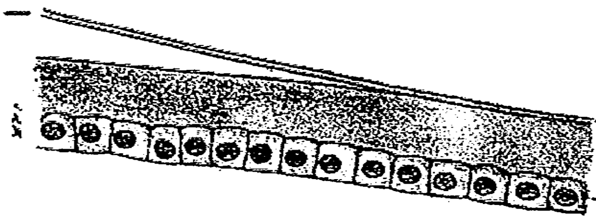
M.Omar

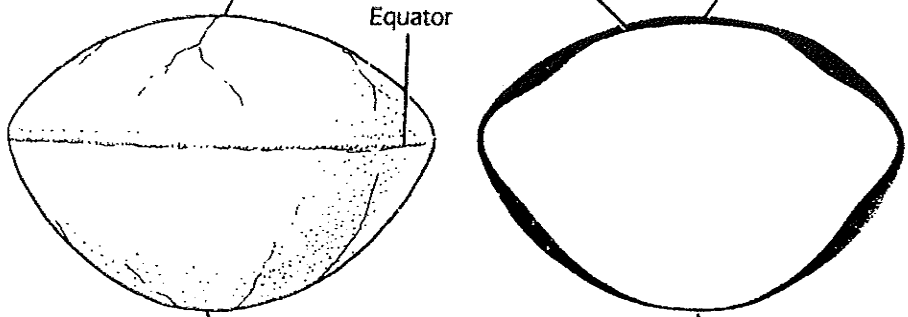
Definition:

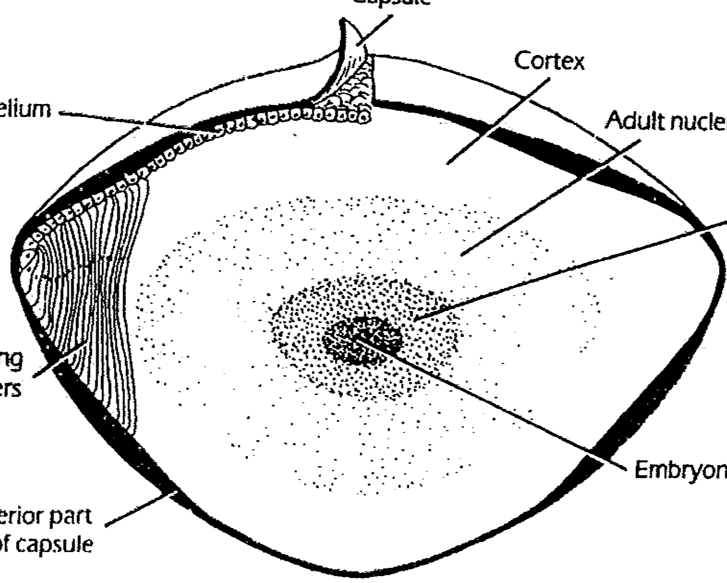
- A grossly transparent, biconvex structure
- located directly
  - behind the iris and pupil &
  - anterior to the lenticular fossa (a shallow depression in the vitreous face)

Gross:

- <u>Site</u>
  - Behind the iris and pupil &
  - Anterior to the lenticular fossa (a shallow depression in the vitreous face)
- <u>Shape</u>: *<u>Biconvex</u>*
  - The **<u>anterior surface</u>** (less convex)
    - The center is the anterior pole
    - The radius of curvature = **10** mm.
  - The **<u>posterior surface</u>**
    - The center is the posterior pole
    - The radius of curvature = **6** mm.
  - The **<u>equator</u>** is separated from the free edge of the processes of the ciliary body by a distance of **0.5** mm.
- **<u>Position & support</u>**:
  - It is held in position by the ciliary zonule.
  - The *<u>zonular fibers</u>* blend into the anterior and posterior lens capsule near the equator & extend further over the anterior than the posterior surface.
  - It is *<u>tilted</u>* (lenticular astigmatism) → being more anterior upper & nasal than lower & temporal.
- **<u>Diameter</u>**: (varries with age) → At birth ⇒ **6.5** mm   adult ⇒ **10** mm
- **<u>Thickness</u>**: (varries with accomodation) → average = **4** mm.
- **<u>Weight</u>**: → **65** mg   (↑ with age → 220 mg)
- **<u>Refractive index</u>**: → **1.386** (Cortex)   **1.406** (Nucleus)
- **<u>Diopteric power</u>**: → **15**
- **<u>Accomodation power</u>**: At birth ⇒ **15** D   At 25 years ⇒ **8** D   At 50 years ⇒ **1-2** D
- **<u>Colour</u>**:
  - Infants & young adults → Transparent, homogenous, crystalline
  - After 35 years → The central portion gets a <u>Yellow</u> tinge
  - Old age → <u>Amber yellow</u>
  - Very old age → <u>Grey</u> (by oblique illumination) = Nuclear sclerosis


Zonular fibre
Zonular lamella
Capsule
Epithelium


Anterior pole
Equator
Posterior pole
Anterior pole
Capsule of lens
Posterior pole


Capsule
Cortex
Anterior epithelium
Adult nucleus
Fetal nucleus
Young lens fibers
Embryonic nucleus
Posterior part of capsule

□ **Microscopic:** The lens is composed of the following:

- **Lens capsule:**

  - <u>Definition</u>: A smooth, homogeneous, acellular elastic membrane that envelops the lens

  - <u>Divided into</u>:
    - ***Anterior capsule*** (thicker) is the basement membrane of the anterior lens epithelium; it is the thickest basement membrane in the body.
    - ***Posterior capsule*** is the basement membrane of lens cells that have their nuclei near the equator of the lens.

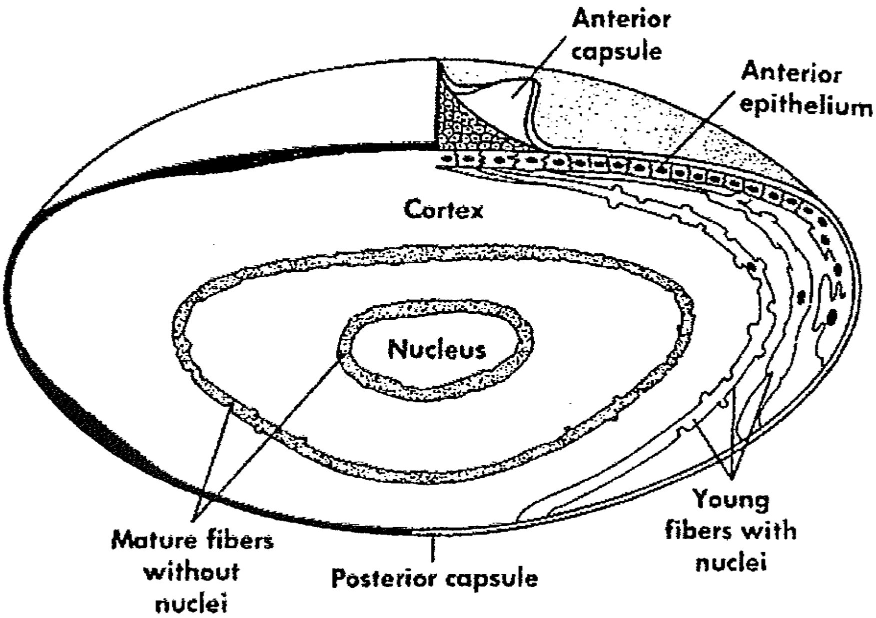
  - <u>Origin</u>:
    - ***Anterior*** → secreted by **lens epithelium**
    - ***Posterior*** → secreted by **superficial lens fibers**

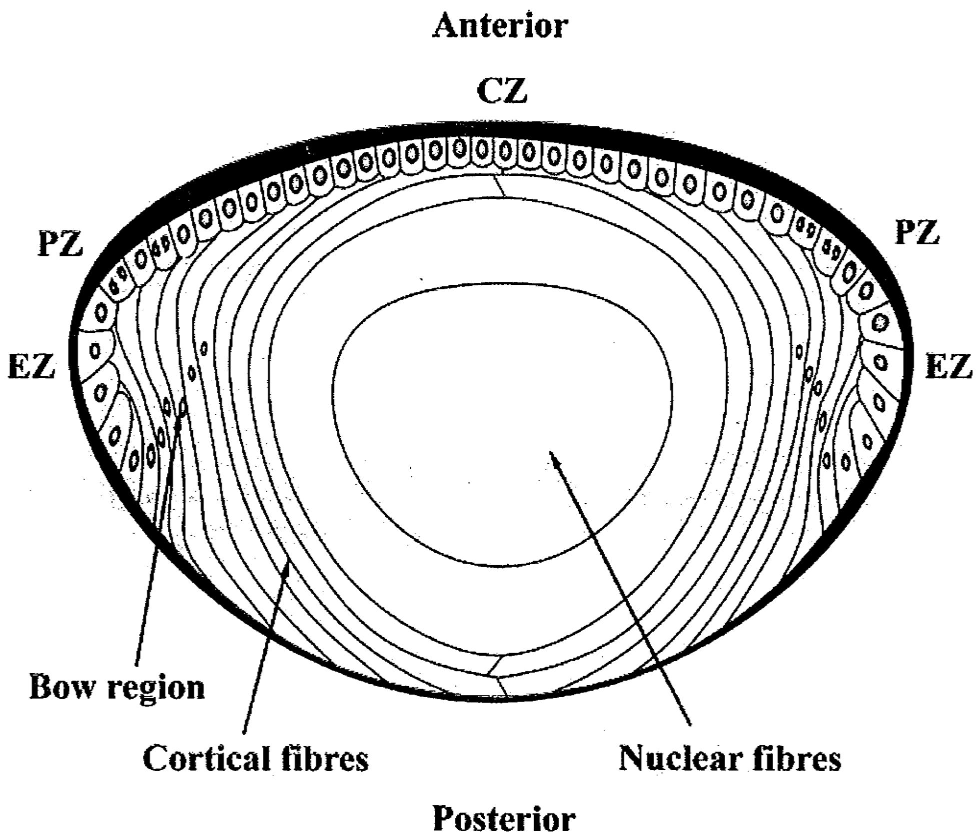
  - <u>Thickness</u>: Average = **4 – 14** μm
    - Differ according to the <u>site</u> :
      - → *Anterior capsule > Posterior capsule*
      - → ***Thickest*** *on the anterior and posterior surfaces just central to the insertion of the zonular fibers.* → *Anterior ring = 24 μm   Posterior ring = 21 μm.*
      - → ***Thinnest*** *on the posterior pole.*
    - Differ according to the <u>age</u> : *Thickness of anterior capsule ↑ with age.*

  - <u>Structure</u>:
    - **Light microscope** → *PAS +ve transparent homogenous structure*
    - **Polarized light** → *Birefringent*
    - **Electron microscope**
      - → ***Lamellar structure:*** *40 lamellae, each is **40** nm thick, consist of Type **IV** collagen fibers embeded in glycosaminoglycans & is **highly elastic** (but doesnt contain elastic tissue)*
      - → ***Zonular lamellae:*** → *the layer of inserting zonular fibers (a narrow zone around the equator) which is less compact & contain more glycosaminoglycans*

  - <u>Properties</u>:
    - Permeability
      - ⇒ *Permeable to* → ***water, ions, small*** *molequles*
      - ⇒ *Impermeable to* → ***protein*** *molecules*
    - Elasticilty → *Highly **elastic** & when torn it rolls outward.*
    - Aging → ↑ *Anterior **thickening*** + ↓ ***Elasticilty***

  - <u>Function</u>: *Molds the lens shape during accomodation*


Anterior capsule
Anterior epithelium
Cortex
Nucleus
Mature fibers without nuclei
Posterior capsule
Young fibers with nuclei


Anterior
CZ
PZ
PZ
EZ
EZ
Bow region
Cortical fibres
Nuclear fibres
Posterior

- **Cells :**

Lens epithelium

Single row of regular cuboidal cells resting on the anterior lens capsule (their BM) and are responsible for the metabolism of the entire lens.

- Cells in the **Resting zone** (central area)
  - ⇨ Cubical (width = 14 μm & length = 7 μm)
  - ⇨ Rarely show mitotic figures
- Cells in the **intermediate zone**
  - ⇨ Narrow elongated
  - ⇨ Show some mitotic figures
- Cells in the **germinal zone** (At the equator)
  - ⇨ ***Maximally elongated*** & become parrallel to the lens capsule → going to form new lens fibers
  - ⇨ Show ***mitotic figures*** (protected from UV rays by iris)

> *Pattern of elongation*: The part of lens cell that is in contact with the capsule becomes the posterior lens fiber, while the opposite end grows into anterior lens fiber.

Lens fibers (lens cells)

- The **Immature lens fiber** (Smooth & well hydrated)
  consists of a cell nucleus and anterior & posterior membranous processes
  - ⇨ The **nuclei** of the most immature cells are located near the equator. As the new cells are fanned, the older cells are pushed inward and form a nuclear bow.
    (as cell move anteriorly their nuclei take a position anterior to the nuclei of the more superficial cells producing an S or C shaped nuclear pattern)
  - ⇨ The **posterior processes** Is in contact with the posterior capsule (its BM)
  - ⇨ The **anterior process** extends forward in the anterior lens cortex.
  - ⇨ Each process is a hexagonal prism
    - Length = **3.5-5** mm
    - Width = **8-10** μm
    - Thickness = **2** μm

> The 1st formed lens fibers are derived from the ***posterior epithelium*** & go from pole to pole
> The later ones are derived from the ***germinal (equatorial) anterior epithelium***

- The **Mature lens fibers** (Irregular & less hydrated)
  - ⇨ Have lost their **nuclei**, and their **posterior processes** are no longer in contact with the posterior capsule.
  - ⇨ Their edges are **serrated** due to ↓ hydration (interdigitating with neighbouring fibers)
  - ⇨ Form most of the substance of the lens. They are packed into lens nucleus
  - ⇨ curved, narrow, membranous cylinder
    Their lateral surface are joined together by ***gap junctions*** & ***ball & socket*** attachment
    Their apical ends are flat with lobulated edges.

- **Cortex :**

composed of ***immature lens fibers*** that have their nuclei near the equator of the lens & their posterior processes attached to the posterior capsule.

> **Deeper cortex** (near the nucleus) is made up of ***mature lens fibers***

- **Nucleus :**

composed of ***mature lens fibers*** (membranes) that lost their nucleii &are no longer attached to a cell nucleus or the posterior capsule. old fibers are compressed centrally to form an increasingly larger inelastic lens nucleus.

  - **Embryonal**: formed in 1st 2 monthes of gestation (contains 1ry lens fibers)
  - **Foetal**: formed in last month of gestation (contains Lens sutures)
  - **Infantile**: formed from the last month of gestation till 25 years
  - **Adult nucleus**: after 25 years

- **Lens sutures :**

  - **Erect anterior** Y-shaped suture: Apex to apex apposition of the corresponding lens fibers from the 2 opposite sides near the anterior pole.
  - **Inverted posterior** Y-shaped suture: Base to base apposition of the detached lens fibers near the posterior pole.

Blood supply:

- The developing lens (in fetal life) → ***Hyaloid artery***
- Thereafter it is avascular→ depends on diffusion from ***aqueous*** & ***vitreous***

Function:

- Refraction
- Accommodation
- Absorption of ultraviolet rays

Changes with Aging:

1) Lens continue to ***grow*** throughout life (doesn't discard any of its contents)
2) Lens becomes ***flatter*** (due to increase nucleus size) → but the refractive power of the lens is retained as flattening of the lens is compensated by ↑ RI of the nucleus
3) ↓ rate of new ***fibers*** formation
4) ↑ thickness of anterior lens ***capsule***
5) Change in the ***colour*** to yellow
6) ↑ rate of ***nuclear*** *sclerosis*
7) Senile ***cataract***

The Zonule of Zinn

(suspensory ligament of the lens)

☐ Definition :

- A ring of fibers passing from the ciliary body to the lens.
- It supports the lens in position & enables ciliary muscle to act on it.

☐ Origin : The mesenchyme (situated at the edge of the optic cup)

☐ Gross :

- Glassy, straight, roughly rounded & fairly grooved **rods**
- **Number** ⇨ **140** bundles arising from **70** ciliary processes
- **Triangular** in a meridional section:
  - Base → **Concave** + Occupies the equator & the adjoining anterior and posterior lens capsules
  - Apex → **Elongated & curved** + Follows the posterior border of ciliary processes then pars plana to ora serrata
  - Antero-external surface (membrane) → In contact with the aqueous of the posterior chamber
  - Postero-internal surface (membrane) → In contact with the anteriror hyaloid of the vitreous

> Canal of **Hannover** → Space between the anterior & posterior membranes.
> Canal of **Petit** → Space between Postero-internal membrane & Anterior hyaloid.

☐ Structure :

- **Light microscope** → PAS +ve ribbons
- **Electron microscope**

> *Microfibrils* collect together forming → *Fibers* collect together forming → *bundles* collect together forming → *Ribbon (appear grossly)*

- **Bundles** ⇨ held together by loose fibrogranular meshwork
- **Fiber**
  - ⇨ Diameter: about 10 μm
  - ⇨ 3 types: 1st order **(thick)** 2nd order **(thin & flat)** 3rd order **(thinnest & circular)**
- **Microfibril**
  - ⇨ beaded structure (electron dens beads held together by filaments)
  - ⇨ Composed of glycoprotein termed **Fibrillin-1**
    (Cysteine concentration is 7 % ⇒ Dislocation is a common feature of homocystinuria)
  - ⇨ Its not collagenous (as thought before) & its structure resembles that of the elastic tissue.

☐ Attachement :

- Capsular attachment:
  - The zonular fibers attach to the **zonular lamellae of the lens capsule** on either sides of the equator.
  - The lens insertion extends about 2 mm in front and 1mm behind the lens equator.
- Cilirary attachment:
  - The zonule attache to the **basement membrane of the ciliary epithelium** at
    - ⇨ the valleys between the ciliary processes.
    - ⇨ the pars plana.
- Other fibers attach to the anterior vitreous face.

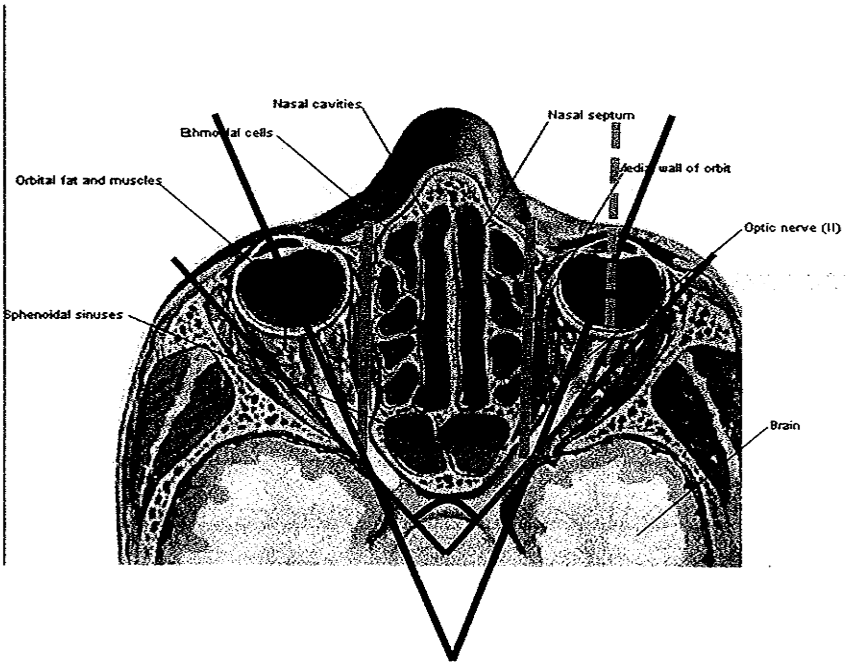
☐ Types of zonular fibers :

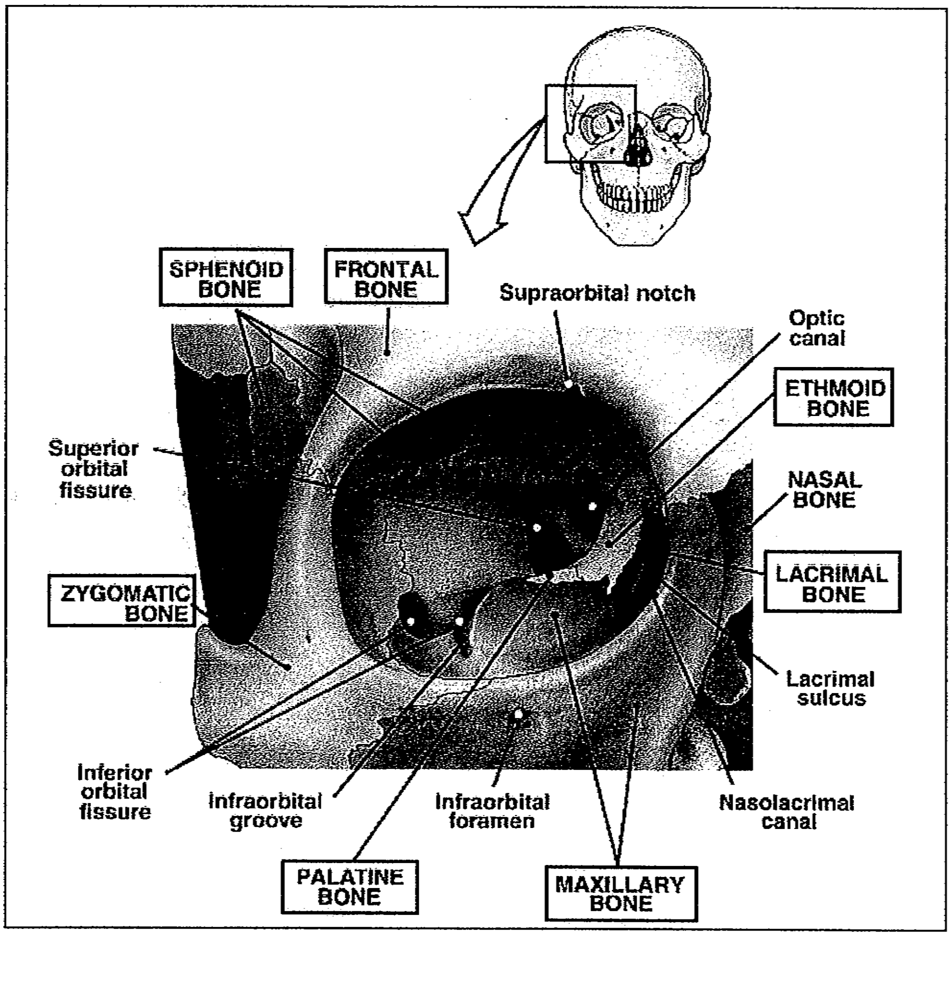
¤ Main fibers:

	Orbiculo-Lental		Cilio-Lental	
	Orbiculo-Posterior capsular fibers	Orbiculo-Anterior capsular fibers	Cilio-Posterior capsular fibers	Cilio-Equatorial fibers
Charachter	The most **posterior**	The **thickest** & **strongest**	The **thinnest** & most **numerous**	Present only in **young** age
Type	2 nd order type	1 st order type	3 rd order type	3 rd order type
Origin	Ora serrata	Pars plana (Orbicularis ciliaris)	Valleys & sides of ciliary processes	Valeys & anterior surface of CP
Course	Lies in close contact to the anterior limiting layer of the vitreous	Lie within valleys of CP & attached to them & to sides of CP by auxillary fibers		
Insertion	Posterior capsule (By ligamentum hyaloideo-capsular of Weiger)	Anterior capsule	Posterior capsule (Anterior to orbiculo-posterior fibers)	Equator

¤ Auxillary fibers:

- Very fine fibers
- Function → ***strengthen the main fibers*** & ***hold various portions of ciliary body together***
- Types → ***Interciliary*** & ***Orbiculo-ciliary*** (between orbicularis ciliaris & posterior ciliary processes) & ***Circular-zonular*** (between anterior hyaloid & zonule)


Nasal cavities
Nasal septum
wall of orbit
Orbital fat and muscles
Optic nerve (II)
Brain


SPHENOID BONE
FRONTAL BONE
Supraorbital notch
Optic canal
ETHMOID BONE
Superior orbital fissure
NASAL BONE
LACRIMAL BONE
ZYGOMATIC BONE
Lacrimal sulcus
Inferior orbital fissure
Infraorbital groove
Infraorbital foramen
Nasolacrimal canal
PALATINE BONE
MAXILLARY BONE

THE ORBIT

- **Quadrilateral pyramid**
  - Base directed → anteriorly, lateral & slightly downwards.
  - Apex directed → Posteriorly, medial & slightly upwards.
  - Widest part is 1.5 cm behind the orbital margin.
- Bones (7) → Frontal + Maxilla + Zygomatic + Sphenoidal + Lacrimal + Ethmoidal + Palatine
- The medial walls are parallel
- The lateral walls diverge at an angle of about 45°.
- The posterior openings of each orbit, the optic foramen and the superior orbital fissure, are located **medial** to the eye.
- The optic nerve, blood vessels, and ocular muscles are **directed laterally**.
- The adult orbit is usually considered to be approximately **40** mm in height, width, and depth and to have a volume of about **29** mL.

The Anterior Margin

(thickened and provides protection for the eye)

⇒ Formed of 3 bones → *Frontal, Maxillary, Zygomatic*.

⇒ Spiral → **Inf. margin** is continuous with ***Ant. lacrimal crest*** & **Sup. margin** is contimuous with ***Post. lacrimal crest***.

- **Lateral margin** (strongest)
  - The *zygomatic* bone.
  - The *zygomatic process of the frontal* bone.
- **Superior margin** (sharp in the lateral **2/3**, rounded in the medial **1/3**)
  - The *frontal* bone.

  ⇒ ***Supraorbital notch or foramen***

  a) Site : (1) At the junction between sharp lateral ⅔ & rounded medial ⅓
  (2) 25 mm from the middle line (3) at the highest part of the arch

  b) Transmits supraorbital n. & a.

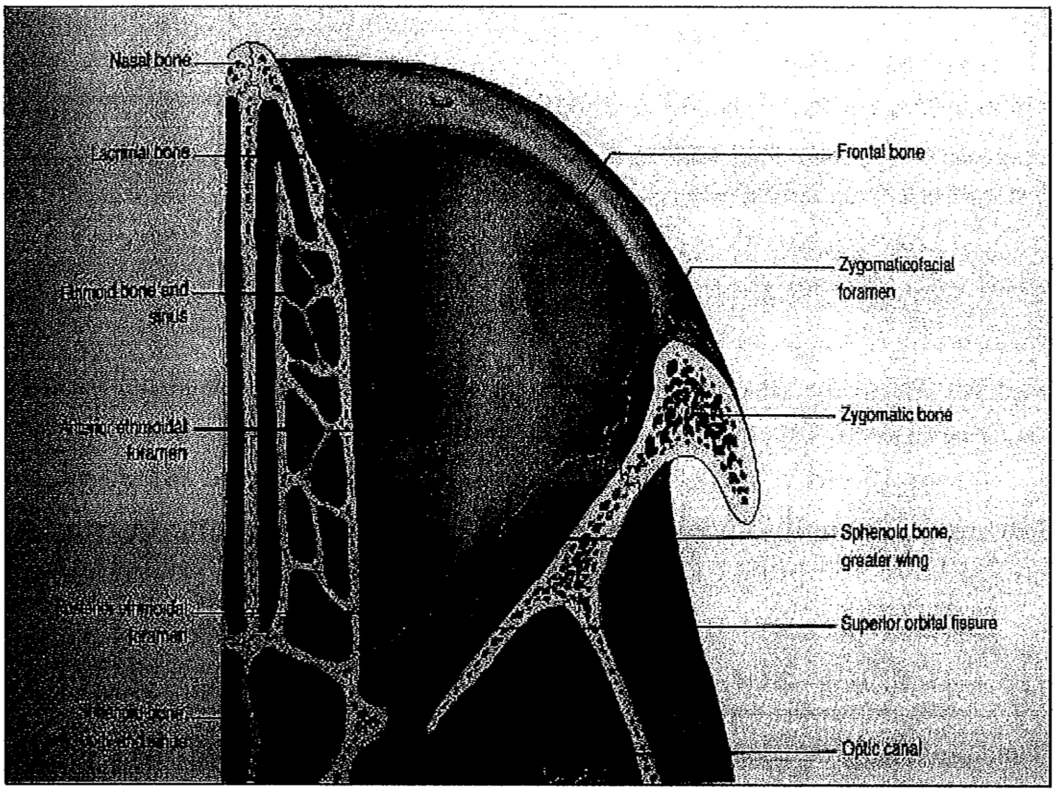
  c) Easily palpable

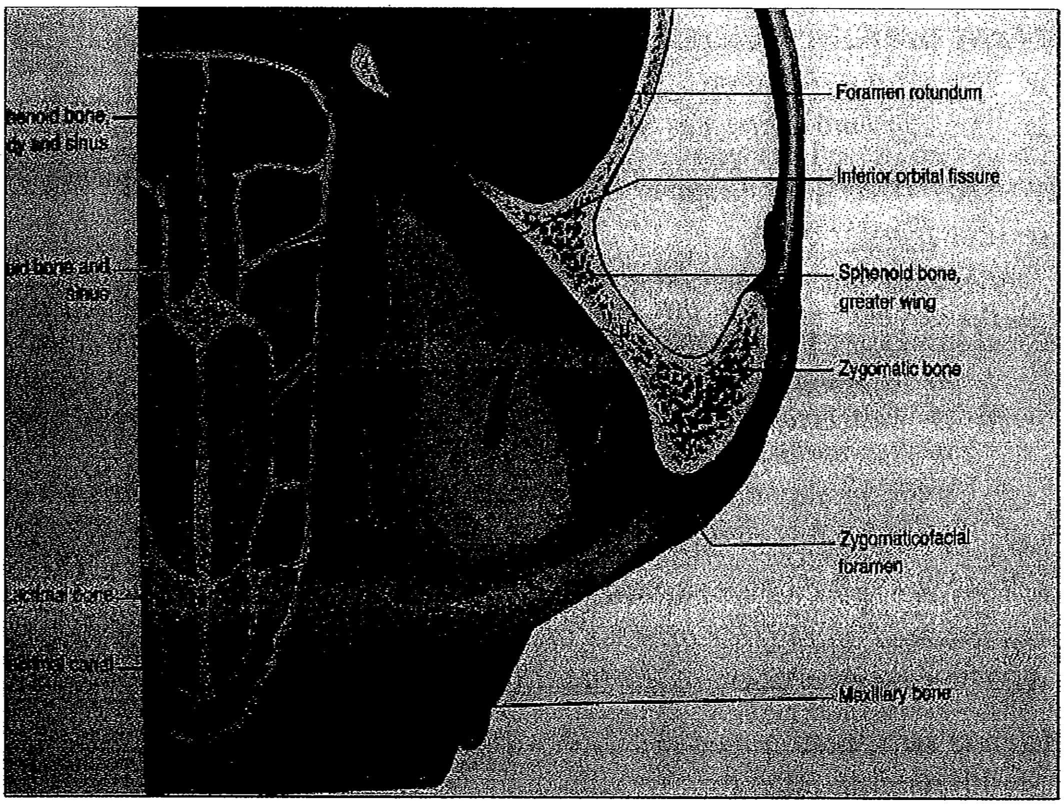
  d) Supraorbital groove may be leading to it.

  ⇒ *Groove for **Supratrochlear** n. & a. may be present medial to supraorbital notch.*

  ⇒ ***Arnold notch or foramen** may be present medial to supraorbital notch.*
- **Medial margin** (poorly defined because of the fossa for the lacrimal sac)
  - The *medial angular process of the frontal bone*.
  - The *frontal process of the maxilla*.
- **Inferior margin** (raised slightly above the floor of the orbit)
  - the *zygoma* laterally.
  - The *body of the maxilla* medially.

  ⇒ ***Infra-orbital foramen** (with a tubercle just above it)*


Nasal bone
Lacrimal bone
Frontal bone
Zygomaticofacial foramen
Zygomatic bone
Sphenoid bone, greater wing
Superior orbital fissure
Optic canal


Foramen rotundum
Inferior orbital fissure
Sphenoid bone, greater wing
Zygomatic bone
Zygomaticofacial foramen
Maxillary bone

Walls

(Each wall of the orbit, except the **medial**, is approximately triangular with the base directed forward)

- **The orbital roof:** [Triangular, concave anteriorly & flat posteriorly]

  1) Formed of:
     - The **Orbital plate of the frontal** bone.
     - The **lesser wing of the sphenoid** bone contributes slightly to the apex.

  2) Features
     - ⇒ The ***Lacrimal gland fossa*** is located in its anterior lateral portion.
     - ⇒ The ***Trochlea*** is located near its anterior medial margin. (4mm behind orbital margin)

  3) Separated from
     a. **Lateral wall** by → ***Superior orbital fissure*** (posteriorly), ***Fronto-zygomatic suture*** (anteriorly)
     b. **Medial wall** by → ***Fronto-maxillary, Fronto-lacrimal, Fronto-ethmoidal, Fronto-sphenoidal*** sutures.

  4) Relations
     - ⇒ **Above** → ***frontal sinus*** anteriorly & ***frontal lobe*** of the brain posteriorly.
     - ⇒ **Below** →
       - ***Frontal n.***, ***Trochlear n.***, ***Supraorbital a.***
       - ***LPS*** (below frontal n.) ***SR*** (below LPS) ***SO*** (betweeb roof & medial wall)
       - ***Lacrimal gland*** & ***Lacrimal n.*** (overlying LR)

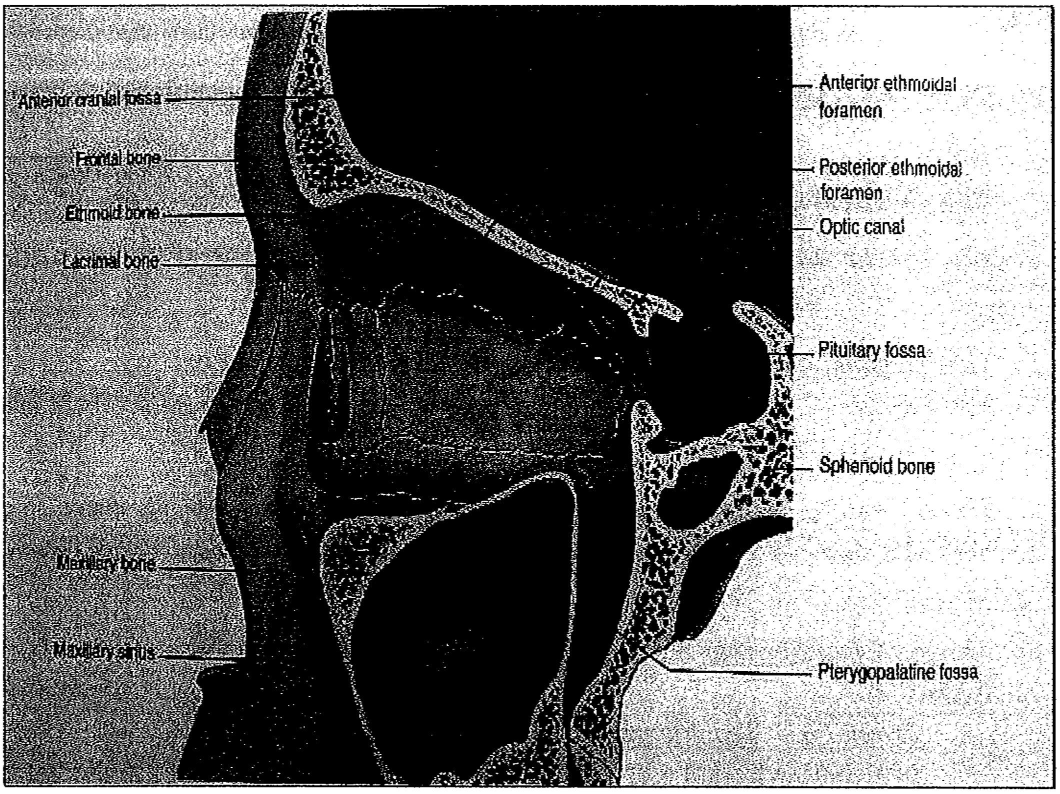
- **The orbital floor:** [Shortest → does not extend to the apex]

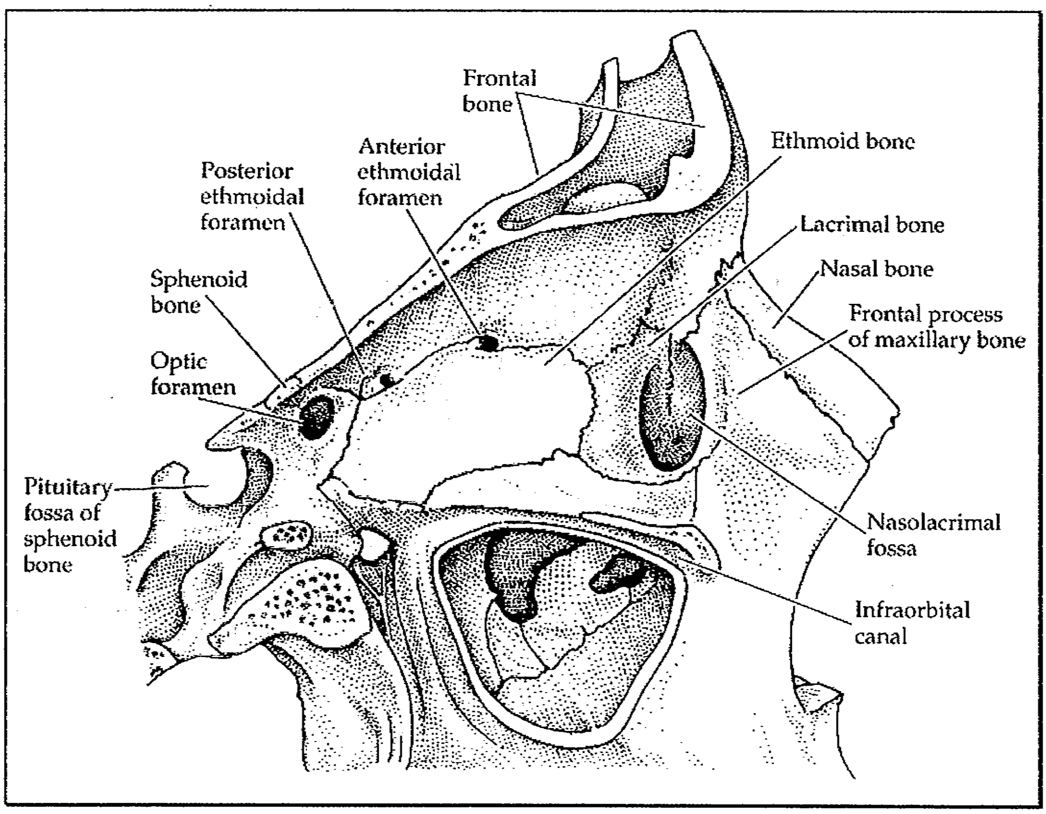
  1) Formed of :
     - The **Orbital plate of the maxilla**. (antero-medial)
     - The **Orbital plate of the zygomatic bone**. (antero-lateral)
     - The **orbital process of the palatine bone** (posterior)

  2) Features :
     - ⇒ The ***infraorbital sulcus*** extend across the floor of the orbit from the IOF. It transmits the infraorbital a. & infraorbital n. At about the midpoint of the orbit the sulcus becomes the ***infraorbital canal*** → the ***infraorbital foramen***, that opens on the face, and transmits the artery and the nerve.
     - ⇒ Bone separates maxillary sinus from orbit is very thin → ***maxillary sinus tumour*** easily invade orbit → proptosis

  3) Separated from
     a. **Lateral wall** by → ***Inferior orbital fissure*** (posteriorly) ***Continuous with zygomatic bone*** (anteriorly)
     b. **Medial wall** by → a fine suture

  4) Relations
     - ⇒ **Below** → ***Maxillary sinus***
     - ⇒ **Above** → ***IR*** (anteriorly), ***IO*** (posteriorly), ***Nerve to IO*** (lateral to IR), ***Infraorbital n & vs***


Anterior cranial fossa
Frontal bone
Ethmoid bone
Lacrimal bone
Maxillary bone
Maxillary sinus
Anterior ethmoidal foramen
Posterior ethmoidal foramen
Optic canal
Pituitary fossa
Sphenoid bone
Pterygopalatine fossa


Frontal bone
Ethmoid bone
Anterior ethmoidal foramen
Posterior ethmoidal foramen
Lacrimal bone
Nasal bone
Sphenoid bone
Frontal process of maxillary bone
Optic foramen
Pituitary fossa of sphenoid bone
Nasolacrimal fossa
Infraorbital canal

- **The medial wall:** [Quadrilateral (oblong) & slightly convex towards the globe]

1) Formation & features:

    - **Frontal process of maxilla**
    - **lacrirmal bone** anteriorly
        - ⇒ *Lacrimal sac fossa* is located between
            1) the anterior lacrimal crest of the frontal process of the maxilla. (its lower end is the ***lacrimal tubercle***)
            2) the posterior lacrimal crest of the lacrimal bone.
        - ⇒ The two leaves of the ***medial canthal ligament*** insert into the anterior and posterior lacrimal crests.
    - The **Orbital plate of the ethmoid bone**,
        - ⇒ The *lamina papyracea* of the ethmoid bone is extremely thin
            1) Sinus may rupture into the orbit when inflamed. (ethmoiditis → orbital cellulitis)
            2) When the lamina papyracea is fractured, it allows air to enter the orbit → surgical emphysema → intermittent proptosis
    - The **body of the sphenoid bone** posteriorly.
        - ⇒ contains the *optic foramen*.

2) Relations:

    - ⇒ **Medial** → Lateral wall of nose, Infundibulum, ethmoidal sinus, sphenoidal sinus

N.B. The lacrimal bone separates the upper ½ of the fossa from ***ethmoid*** sinus & lower ½ of fossa from ***middle meatus*** of the nose.

    - ⇒ **Lateral**
        - **MR** (along the medial wall), **SO** (between medial wall & roof) and in between:
            1. ***Ophthalmic a.*** (and its terminal branches)
            2. ***Ethmoidal ns & as*** (anterior and posterior)
            3. ***Infratrochlear n.***
        - **Lacrimal sac**

- **lateral wall:** [Thickest → strongest (more exposed to stress)]

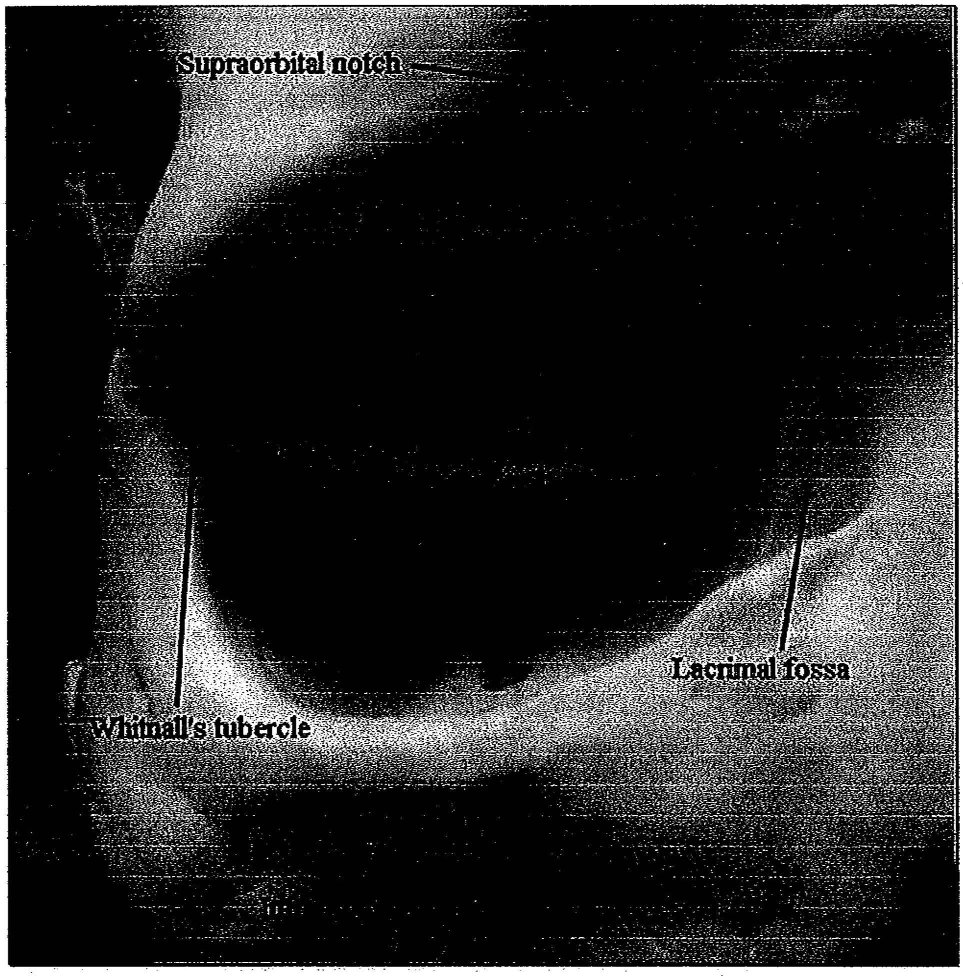
1) Formation & features :

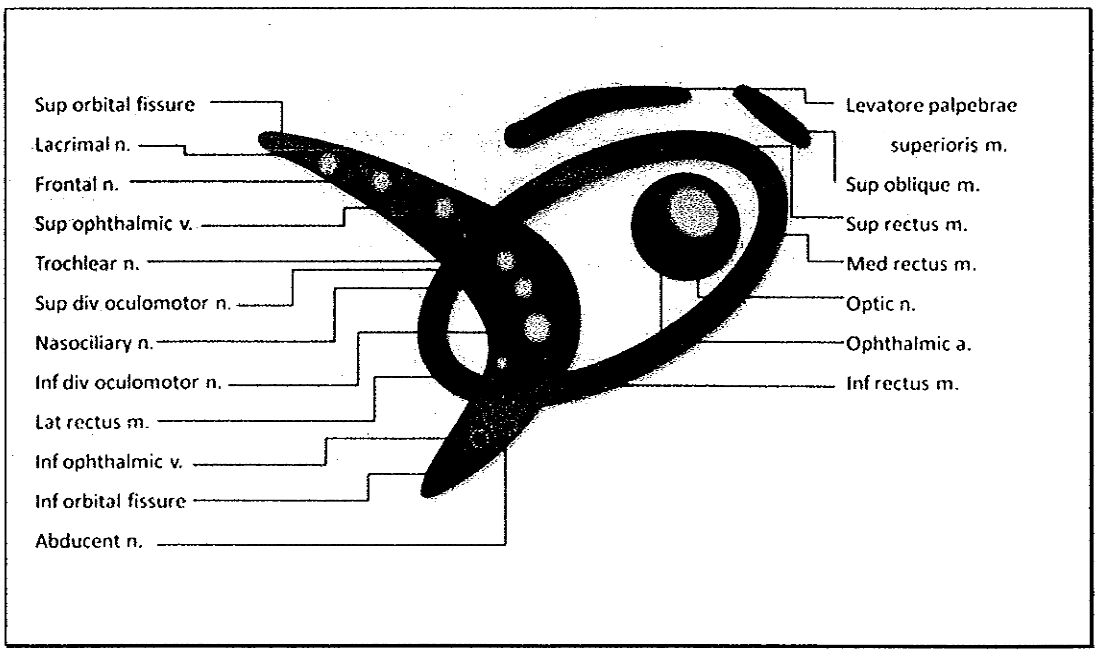
  - The **Zygoma** anteriorly.
    - → Thick & separates the orbit from the ♣ ***Temporal fossa.***
    - → ***Lateral orbital tubercle (whitnall)*** is situated on the anterior margin of the lateral wall, to it is attached:
      - ⇒ the aponeurosis of the levator palpebrae superioris muscle.
      - ⇒ the suspensory ligament of the globe (lig. of Lock-wood),
      - ⇒ the check ligament of the lateral rectus muscle.
      - ⇒ The lateral palpebral ligament.
    - → ***Zygomatic groove*** (from anterior end of IOF) → ***Zygomatic foramen*** → ***zygomatic canal*** (contains zygomatic n. & vs) → divides into 2 canals that open through
      - ⇒ ***Zygomatico-facial foramen*** → (check)
      - ⇒ ***Zygomatico-temporal foramen*** → (temporal fossa)

  - The **greater wing of the sphenoid** posterior 2/3
    - → Thin & separates the orbit from the ♣ ***middle cranial fossa*** ***(temporal lobe of the brain)***
    - → ***Spina recti lateralis***: Small bony projection situated on the inferior margin of SOF ⇒ gives partial attachment to LR.

2) Relation

  - **Lateral** → ***Temporal fossa*** (anteriorly) ***Middle cranial fossa*** (posteriorly)
  - **Medial** → ***LR*** (along the whole lateral wall) ***Lacrimal n. & a.*** (above LR)


Supraorbital notch
Lacrimal fossa
Whitnall's tubercle


Sup orbital fissure
Lacrimal n.
Frontal n.
Sup ophthalmic v.
Trochlear n.
Sup div oculomotor n.
Nasociliary n.
Inf div oculomotor n.
Lat rectus m.
Inf ophthalmic v.
Inf orbital fissure
Abducent n.
Levatore palpebrae superioris m.
Sup oblique m.
Sup rectus m.
Med rectus m.
Optic n.
Ophthalmic a.
Inf rectus m.

Optic Foramen

□ **Definition:** The orbital opening of the optic canal.

□ **Site:**

- Posterior medial portion of the orbit
- In the ***body of the sphenoid bone***

□ **Communicates:** ⇒ ***Orbit*** & ***Middle cranial fossa***

□ **Dimentions:**

- **Length** → of optic canal ≈ **4-10** mm (Lateral wall ≈ **5-7** mm Roof ≈ **10-12** mm)
- **Diameter** → Orbital opening ≈ **6 X 5** mm Cranial opening ≈ **4 X 5** mm
- **Distance** → between the the 2 canals
  - At the cranial openings ≈ **25** mm
  - At the orbital openings ≈ **30** mm

N.B. The longer the canal → the narrower it is

□ **Shape:**

- ***Funnel shaped*** with the base anteriorly
- Orbital opening → **vertically** oval, middle portion → **circular**, Cranial opening → **horizontally** oval

□ **Boundaries:**

- Between the 2 roots of lesser wing of sphenoid
- Medially → Sphenoid sinus (sometimes posterior ethmoid sinus)
- Laterally → Posterior root of lesser wing of sphenoid separating the canal from medial end of SOF, with the infraoptic tubercle on it.
- Above → Posterior part of gyrus rectus + olfactory tract.

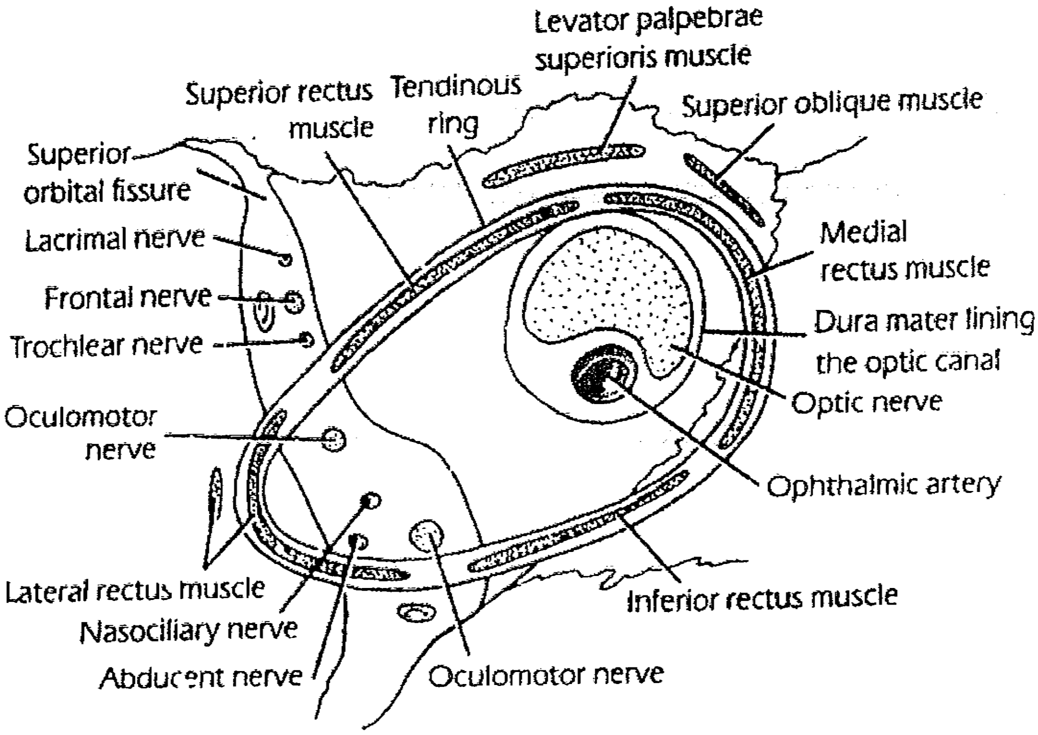
□ **Direction:** → ***Forwards***, ***laterally*** & slightly ***downwards***. (making an axis of **36°** with sagital plane)

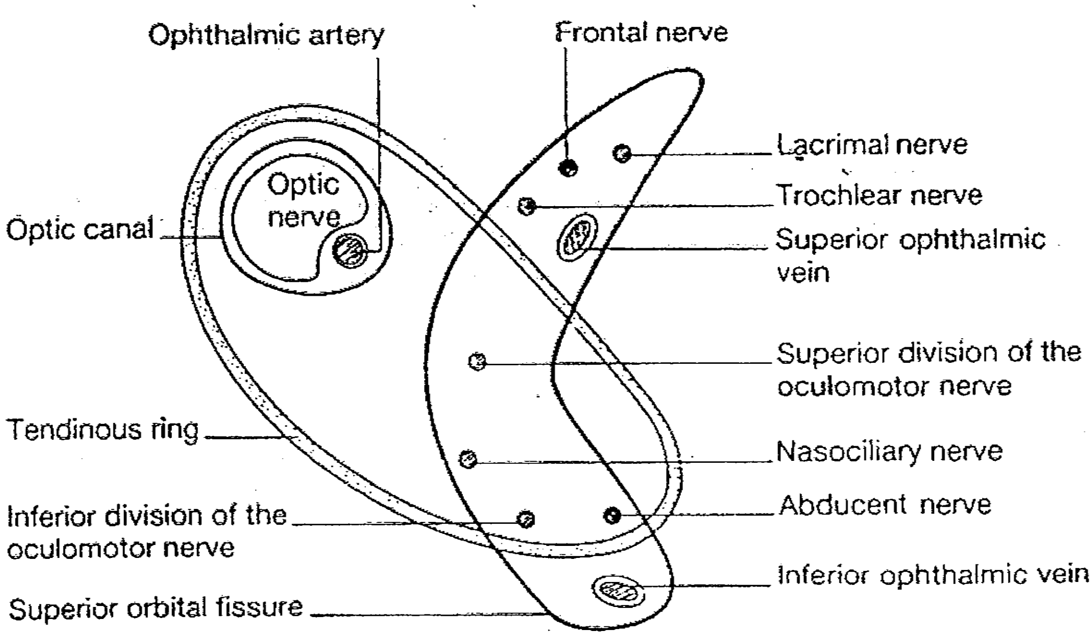
□ **Structures passing:**

- ***Optic nerve***, (The dura mater of the meninges that surrounds the optic nerve in the optic foramen divides into two layers at the orbital apex. One layer forming **orbital periosteum**; The other continues forward as the **dural sheath** of the optic nerve)
- ***Ophthalmic a.*** (below & lateral to the nerve → embeded in the dura)
- ***Sympathetic*** nerves from the carotid plexus.

□ **The annulus of Zinn:**

- Definition: Thickening of the peri orbita at the apex of orbital cavity
- Contents: encircles the ***optic foramen*** & the ***medial portion of the superior orbital fissure***
- Attachment:
  - Medially ⇒ into the cleft formed by the splitting of the periorbita
  - Laterally ⇒ attached at the spina recti lateralis.
- Thickening:
  - Lower tendon of Zinn ⇒ gives origin to IR and part of MR & LR
  - Upper tendon of Lockwood ⇒ gives origin to SR and part of MR & LR


Levator palpebrae
superioris muscle
Superior rectus
muscle
Tendinous
ring
Superior oblique muscle
Superior
orbital fissure
Lacrimal nerve
Frontal nerve
Trochlear nerve
Medial
rectus muscle
Dura mater lining
the optic canal
Optic nerve
Oculomotor
nerve
Ophthalmic artery
Lateral rectus muscle
Nasociliary nerve
Abducent nerve
Oculomotor nerve
Inferior rectus muscle


Ophthalmic artery
Frontal nerve
Optic
nerve
Optic canal
Lacrimal nerve
Trochlear nerve
Superior ophthalmic
vein
Superior division of the
oculomotor nerve
Tendinous ring
Nasociliary nerve
Abducent nerve
Inferior division of the
oculomotor nerve
Inferior ophthalmic vein
Superior orbital fissure

Superior Orbital Fissure

Site:

- Between the roof & lateral orbital wall
- Separates the greater and lesser ***wings of the sphenoid bone***.

Communicates: ⇒ *Orbit* & *Middle cranial fossa*

Dimention: ⇒ Longitudinal axis = 22 mm

Shape:

- Coma shaped or Oval or Elongated oval
- **Wider** medially (below optic foramen) **narrower** laterally

Boundaries:

- Above ⇒ Posterior root of lesser wing of sphenoid
  - Separates The medial end of SOF from optic foramen
  - ***Infraoptic tubercle*** → present on it (below and lateral to the opic foramen)
- Below ⇒ greater wing of sphenoid
  - ***Spina recti lateralis*** → Small bony projection at the junction between the wide & narrow parts.
- Laterally ⇒ closed by frontal bone
- Medially ⇒ continuous with ***IOF***

Structures attached:

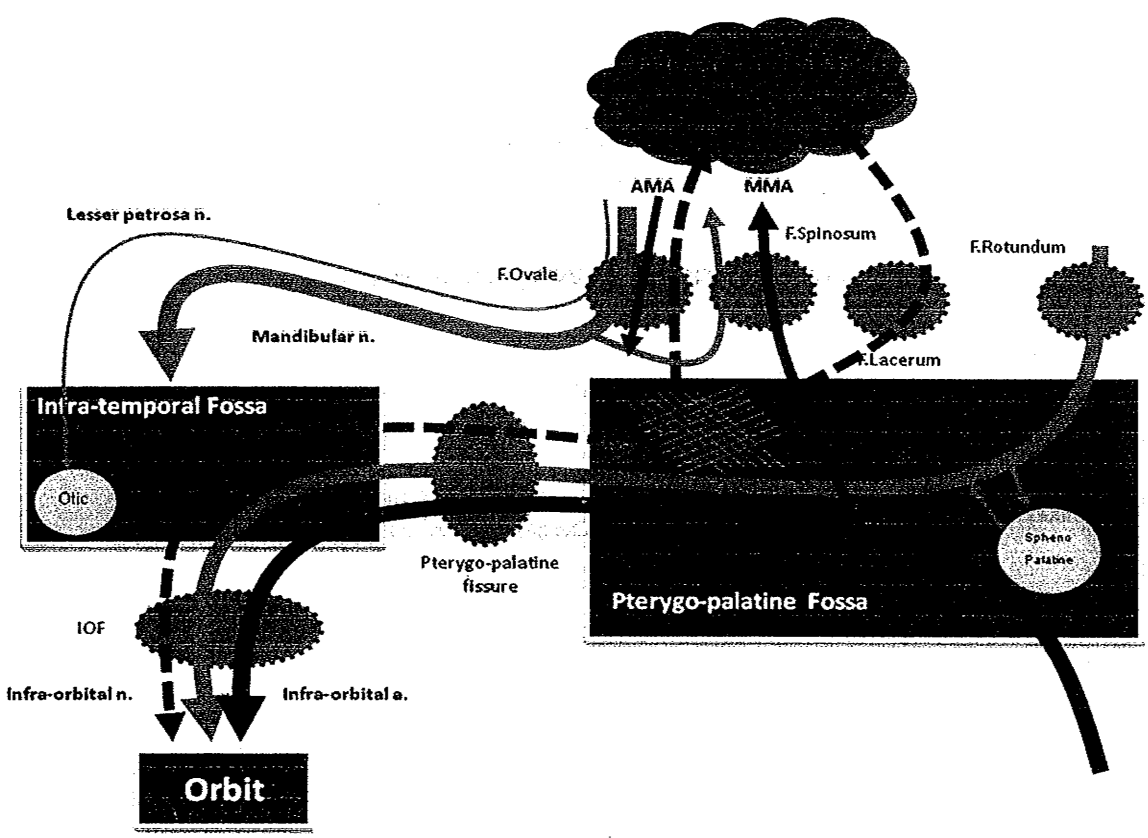
- ***Common tendinuous annulus of Zinn*** → Spina recti lateralis.
- ***Lateral rectus*** → From the common tendon + Spina recti lateralis.

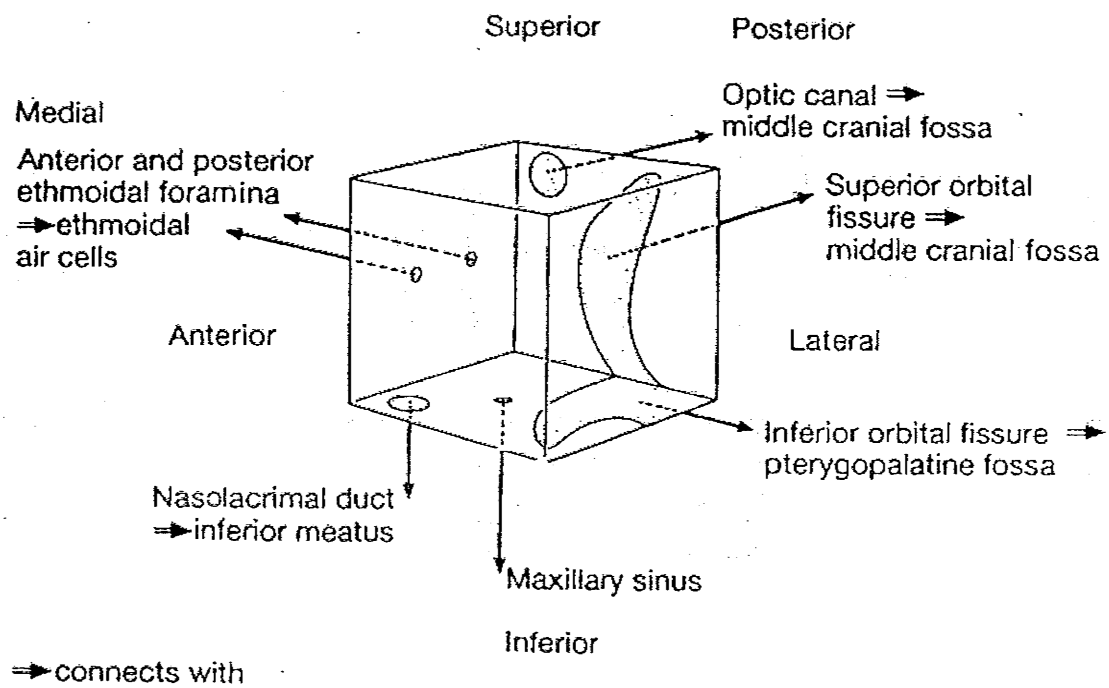
Structures passing: (Live Free To Really See No Insult At All)

- Outside annulus of Zinn
  1) Above the annulus (from lateral portion of the SOF)
     - **Lacrimal** n.
     - **Frontal** n.
     - **Trochlear** n.
     - **Reccurent meningeal a. (branch of ophthalmic a. or lacrimal a.)**
     - **Superior ophthalmic v.** (may pass inside the annulus)
  2) Below the annulus
     - **Inferior ohthalmic v.**
- Within the annulus of zinn. (between 2 heads of LR)
  - **Oculomotor** n. (Superior & Inferior divisions)
  - **Nasociliary** n. (between superior & inferior divisions of oculomotor)
  - **Abducent** n. (laterally)
  - **Sympathetic** root to ciliary ganglia.

L = **lacrimal n.**
F = **Frontal n.**
T = **Trochlear n.**
R = **Reccurent n.**
S = **Sup div. of 3rd**
N = **nasociliary n.**
I = **Inf. div. of 3rd**
A = **Abducent n.**

Age changes: ⇒ It is wider in **yound children** then becomes narrower in **adulthood** by growth of greater wing of sphenoid.


AMA
MMA
Lesser petrosa n.
F.Spinosum
F.Rotundum
F.Ovale
Mandibular n.
F.Lacerum
Infra-temporal Fossa
Otic
Pterygo-palatine fissure
Spheno Palatine
Pterygo-palatine Fossa
IOF
Infra-orbital n.
Infra-orbital a.
Orbit


Superior
Posterior
Medial
Optic canal ⇛ middle cranial fossa
Anterior and posterior ethmoidal foramina ⇛ethmoidal air cells
Superior orbital fissure ⇛ middle cranial fossa
Anterior
Lateral
Inferior orbital fissure ⇛ pterygopalatine fossa
Nasolacrimal duct ⇛inferior meatus
Maxillary sinus
Inferior
⇛connects with

Inferior Orbital Fissure (Spheno-maxillary)

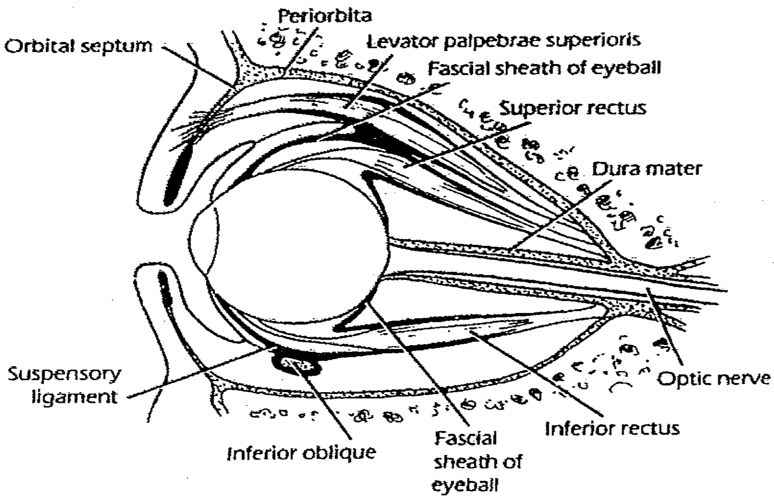
- **Site**:
  - Between the floor & lateral orbital wall
  - Separates the ***greater wing of the sphenoid*** bone from the ***maxillary bone***. ie. spheno-maxillary
  - Below and lateral to the optic foramen & close to the medial end of SOF
- **Communicates** ⇒ ***Orbit*** with ***Pterygo-palatine*** & ***Infra-temporal*** fossae.
- **Boundaries**:
  - Anteriroly → Orbital plate of maxilla & orbital plate of palatine
  - Posteriroly → Orbital plate of greater wing of sphenoid bone
  - Lateral border → Sharp & higher anteriroly than medial
  - Closed by → Periorbita + Muller's muscle.
- **Direction** ⇒ *Forward* & *laterally* for 20 mm
- **Structures passing**:
  - ***Infraorbital n.*** & ***Zygomatic n.*** (Branches of maxillary n.)
  - ***Infraorbital a.***
  - Anastomosis between the ***inferior ophthalmic vein*** & the ***pterygoid plexus***. (Emissary v.)
  - Orbitociliary n. (branch of mandibular)
- **Age changes** ⇒ It is wider in **yound children** then becomes narrower in **adulthood** by growth of greater wing of sphenoid & maxillary air sinus.

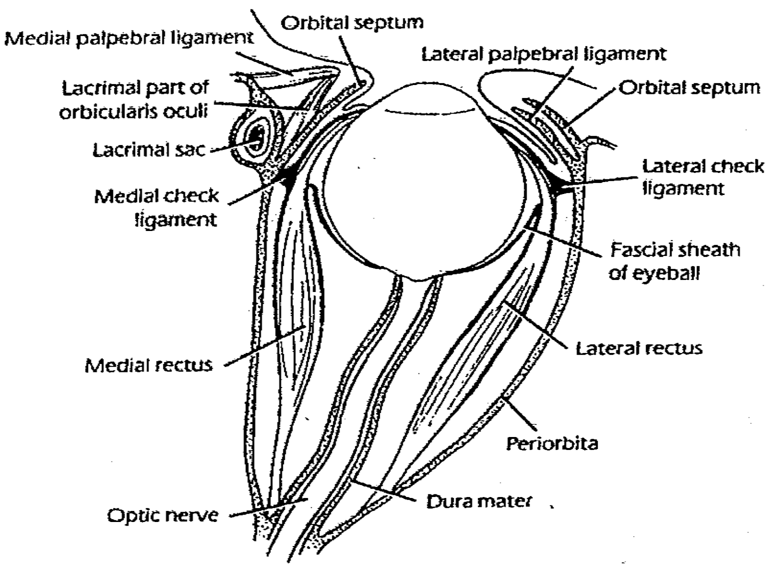
Ethmoidal Foramina

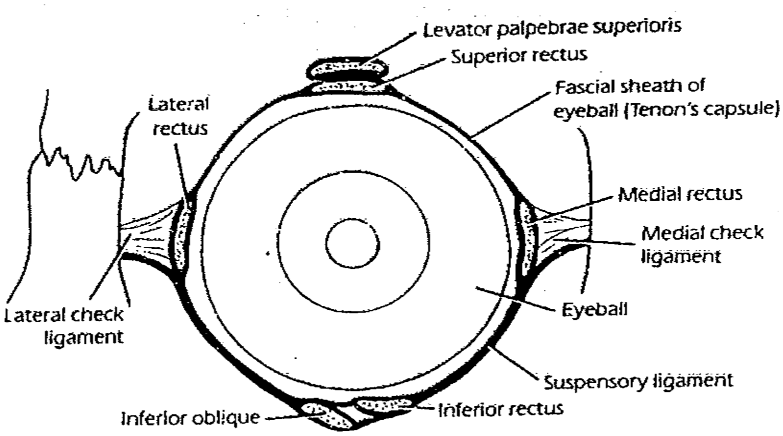
- Site → **between** roof & medial wall   **In** the fronto-ethmoid sutrure or in Frontal bone

  N.B. They are formed by **frontal** & completed by **ethmoidal** bones.
- Communicates : ***Orbit*** & ***Anterior cranial fossa***
- Structures passing → Anterior ethmoidal n. & a.   Posterior ethmoidal n. & a.

Foramina outside orbit	Site	Passing
Supraorbital notch or foramen	Just above the superior orbital margin, at the junction between the sharp lateral ⅔ & rounded medial ⅓	**Supraorbital** n. & vs
Arnold Notch or foramen	Present sometimes medial to supraorbital foramen	medial branches of **supraorbital** n. & vs
Supraciliary canal	Present in 50 % of cases Near supraorbital foramen	Branch of **supraorbital** n. To frontal air cells
Infra-orbital foramen	½ cm below the tubercle of the lower orbital margin directed → ***Downwards, forwards & medially***	**Infraorbital** n. & vs
Zygomatic groove & foramen	***Zygomatic groove*** (from anterior end of IOF) → ***Zygomatic foramen*** → ***Zygomatic canal*** → divides into 2 canals that open through ⇒ *Zygomatico-facial foramen* → (check) ⇒ *Zygomatico-temporal foramen* → (temporal fossa)	**Zygomatic** n. & vs.


Periorbita
Orbital septum
Levator palpebrae superioris
Fascial sheath of eyeball
Superior rectus
Dura mater
Suspensory ligament
Optic nerve
Inferior rectus
Inferior oblique
Fascial sheath of eyeball


Orbital septum
Medial palpebral ligament
Lateral palpebral ligament
Lacrimal part of orbicularis oculi
Orbital septum
Lacrimal sac
Lateral check ligament
Medial check ligament
Fascial sheath of eyeball
Lateral rectus
Medial rectus
Periorbita
Optic nerve
Dura mater


Levator palpebrae superioris
Superior rectus
Fascial sheath of eyeball (Tenon's capsule)
Lateral rectus
Medial rectus
Medial check ligament
Eyeball
Lateral check ligament
Suspensory ligament
Inferior oblique
Inferior rectus

Orbital Fascia

□ The **periorbita (periosteum of the orbit)**

- Derived from the dura mater, which splits at the optic foramen into 2 layers, one constitutes the periosteum & the other continues as the optic n. dural sheath.

□ The **orbital septum (palpebral fascia)**

- Extends from the bony margins of the orbit to the eye lid in close relationship with the posterior surface of the palpebral portion of the orbicularis oculi muscle.
- It divides the orbit into anterior and posterior portions.
- The septum prevents orbital fat from entering the eyelids and limits the spread of inflammation from the eye lid into the orbit.

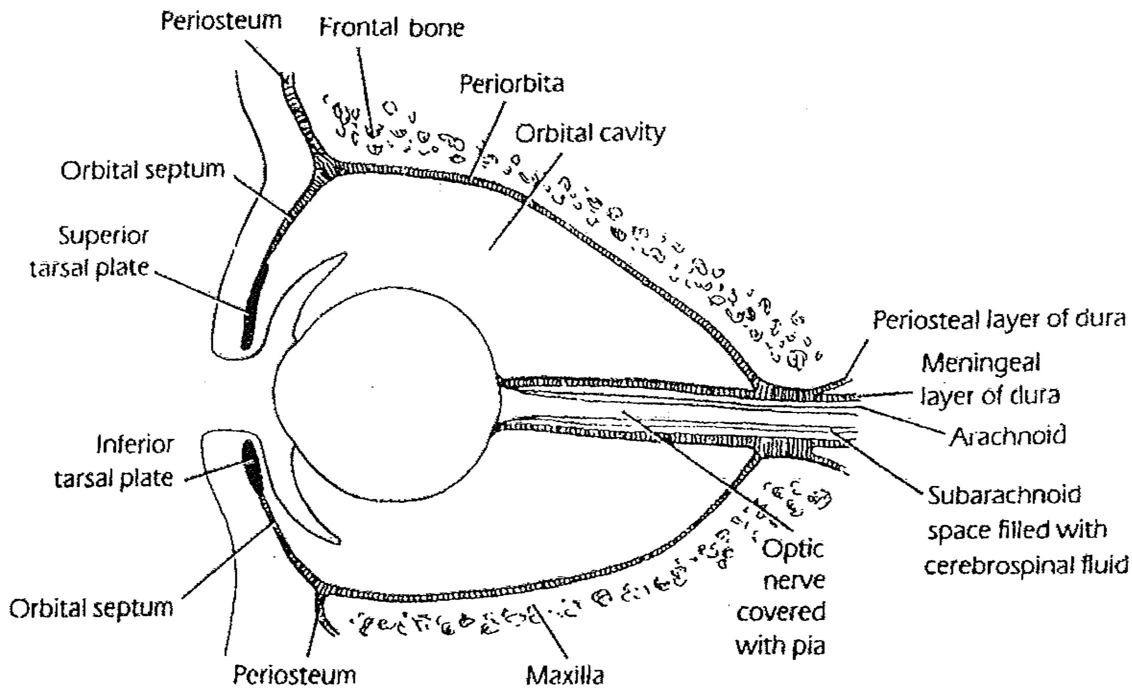
□ The **bulbar fascia (Tenon capsule)**

- Separates the globe from orbital fat and provides the socket in which the eye moves.
- Anteriorly it extends to the insertion of the conjunctiva at the corneoscleral limbus. (separated from the conjunctiva by loose C.T)
- Its lower portion is thickened to form ***the suspensory ligament of Lockwood***, upon which the globe rests.
- Posteriorly it is in contact with the orbital fat (difficult to separate)
- Perforations: Posteriorly ⇒ *optic n, ciliary vessels, ciliary nerves*, *vortex vs*
  Anteriorly ⇒ *6 Extra-ocular ms.*

□ The **muscular fascia**

- Surrounds the ocular muscles, particularly their anterior portions.
- ***Check ligaments***. Expansions of the muscular fascia (especially that covering the medial & lateral recti muscles) to the orbital margins. (Check = Limit ms action to an extent)
  - **Lateral rectus** expansion → Orbital tubercle of the ***zygomatic bone*** (Whitnall's tubercle)
  - **Medial rectus** expansion → ***Lacrimal bone*** *(Posterior lacrimal crest)*
  - **Superior rectus** expansion → ***Levator palpebrae superioris*** ⇒ Ensure the synergestic actions of the 2 muscles (when the eye looks up by SR → the lid is raised by LPS.
  - **Inferior rectus** expansion → between ***tarsal plate & orbicularis*** ⇒ lower lid depression
  - **Superior oblique** expansion → ***Trochlea***
  - **Inferior oblique** expansion → ***Orbital floor*** (lateral part)

  Function :
  1. Support of the eye ball within the orbital cavity
  2. Assist orbital septum to prevent herniation of orbital fat
  3. From the ant. End of the all expansions → fibrous band attach to the conjunctival cul-de-sac ⇒ Pulling the conjunctiva when the muscles act ⇒ prevent it from infolding.



Periosteum
Frontal bone
Periorbita
Orbital cavity
Orbital septum
Superior tarsal plate
Periosteal layer of dura
Meningeal layer of dura
Arachnoid
Inferior tarsal plate
Subarachnoid space filled with cerebrospinal fluid
Optic nerve covered with pia
Orbital septum
Periosteum
Maxilla

Periorbita

- **Definition:** Orbital periostem that lines the bony orbit

- **Fixation:**
  - Loosely adherent to the bone
  - Fixed at:
    1. Orbital margin → continuous with Orbital septum.
    2. Sutures.
    3. Fissures & foramina.
    4. Lacrimal fossa.

- **Behaviour at different parts:**
  - *Optic foramen* → Splits
    - Layer continuous with the dura covering optic nerve
    - Lamellar processes divide the fat into lobules & form covering of the blood vessels
  - ***Superior orbital fissure*** → becomes continuous with endosteal layer of dura.
  - ***Anterior ethmoidal canal*** → becomes continuous with endosteal layer of dura.
  - ***Inferior orbital fissure*** → continuous with periosteum of *infratemporal* & *pterygopalatine* fossa.
  - ***Temporal canal*** → continuous with periosteum of *temporal fossa*
  - ***Zygomatic canal*** → continuous with periosteum on the *front of zygomatic bone*.
  - Orbital apex → ***Common tendinuous ring*** (periosteal thickening around optic canal & medial part of SOF)
  - ***Lacrimal fossa*** → it gives a layer to enclose the lacrimal sac → pass down to form the periosteum of NLD → continuous with periosteum of the inferior meatus.

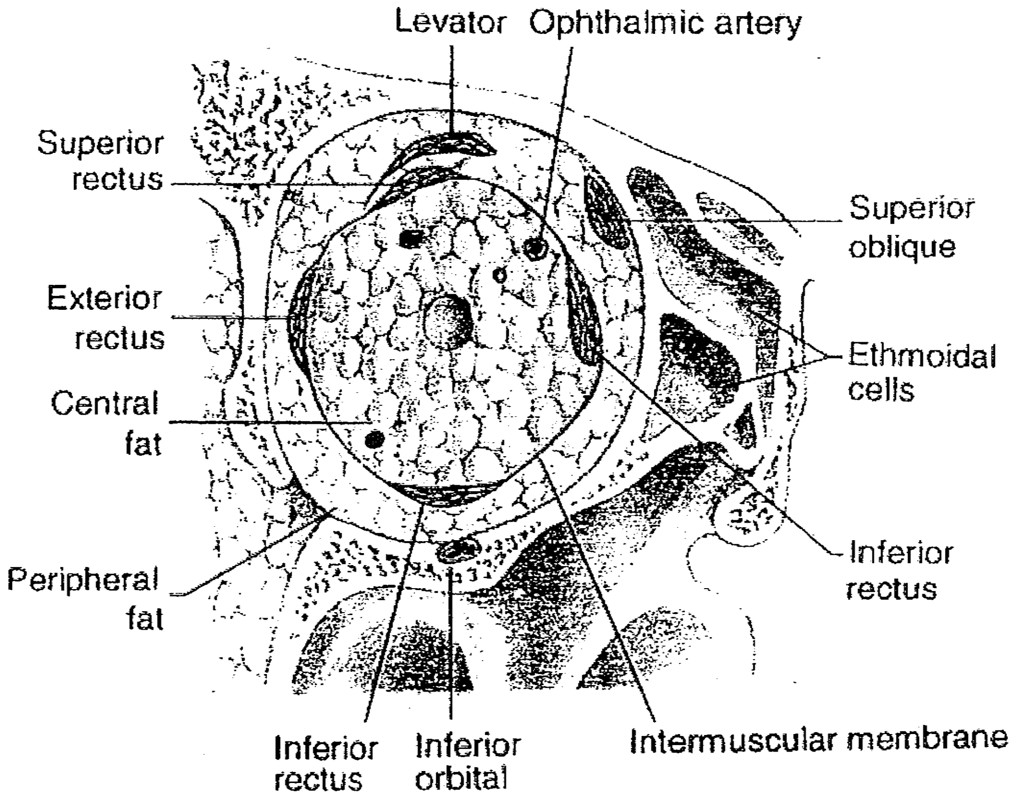
- **Structure:**
  - 2 layers ⇒
    (1) Outer layer (with oblique fibers)
    (2) Inner layer (with no oblique fibers) → gives covering to *Frontal & lacrimal ns* & form space for ***lacrimal gland.***
  - Ossification may occur where it
    (1) Roofs **infraorbital** canal
    (2) Gets attached to **posterior lacrimal crest**

- **Nerve supply:** ⇒ Branches of ***Trigeminal nerve***
  - ***Ophthalmic n.*** → Frontal + Lacrimal + Ethmoidal
  - ***Maxillary n.*** → Zygomatic + Infraorbital

- **Applied anatomy**:
  - Periorbita is loosely attached to bones in most parts → may be ***lifted by blood or pus.***
  - During ***Orbital Exentration*** → we have to remember the sites of firm attachments (to the margins of foramina & fissures

- **Sagital section:**

Periosteal layer of ***dura*** + ***Periorbita*** + ***Periosteum*** (at foramina) + ***Orbital septum*** + ***Tarsus*** ⇒ Are continuous



Levator
Ophthalmic artery
Superior rectus
Exterior rectus
Central fat
Peripheral fat
Superior oblique
Ethmoidal cells
Inferior rectus
Inferior rectus
Inferior orbital
Intermuscular membrane

Orbital Fat

Intermuscular membrane joins the sheathes of the 4 recti together.

- Posteriorly → It is thin & deficient ⇒ Peripheral & central fat are continuous.
- Anteriorly → It is thick & continuous with Tenon's capsule ⇒ dividing fat into:
  - **Central fat (Intramuscular)**
    - ⇒ Loose around optic nerve and ciliary nerves & vessels → allow movement.
    - ⇒ It has a limiting membrane separated from the dura of the optic nerve with a space called → ***Supra vaginal space of schwalbe.***
  - **Peripheral fat (Extramuscular)**

⇒ Limited anteriorly by the ***Orbital septum.***

⇒ Between ***Periorbita*** & ***Recti*** muscles (with the intermuscular membrane inbetween)

⇒ Covered with thin C.T membrane in contact with → Muscles Sheathes , Periorbita, Orbital septum

⇒ It forms 4 lobes ⇒ Supero-lateral, Infero-lateral, Supero-medial, Infero-medial lobes

⇒ Prevented from herniation by ⇒ **(1)** Orbital septum **(2)** Check ligaments (fascial expansions)

⇒ *Apertures through which fat may herniate to contact the orbital septum:*

1) **Superior** aperture ⇒ Between ***Orbital roof*** & ***Levator ms***. → supero-medial lobe herniate → Retroseptal roll
2) **Supero-medial** aperture ⇒ Between ***SO expansion*** & ***medial check ligament***. → Supero-medial lobe herniate → the common lobulated prominance in old people.
3) **Infero-medial** apertue ⇒ between ***IO origin*** & ***medial check ligament***.
4) **Inferior** aperture ⇒ Between ***IO expansion*** & ***Orbital floor***.
5) **Infero-lateral** aperture ⇒ Between ***IO expansion*** & ***Lateral check ligament***.

Blood & puss pass out of the orbit through these apertures (from space between orbital fat & periorbita) → *Stopped by Orbital septum*

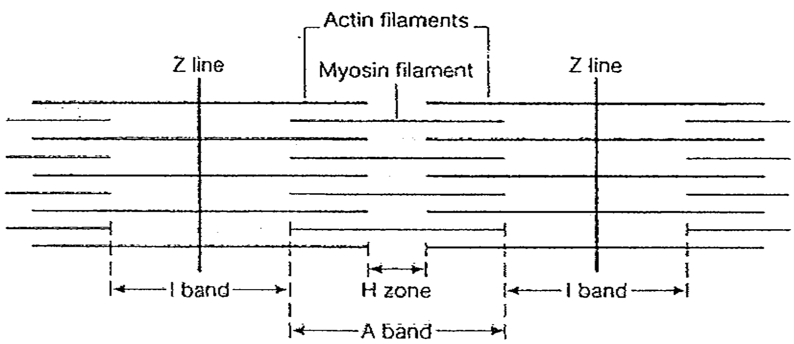
Surgical considerations

Four spaces are present inside the orbit

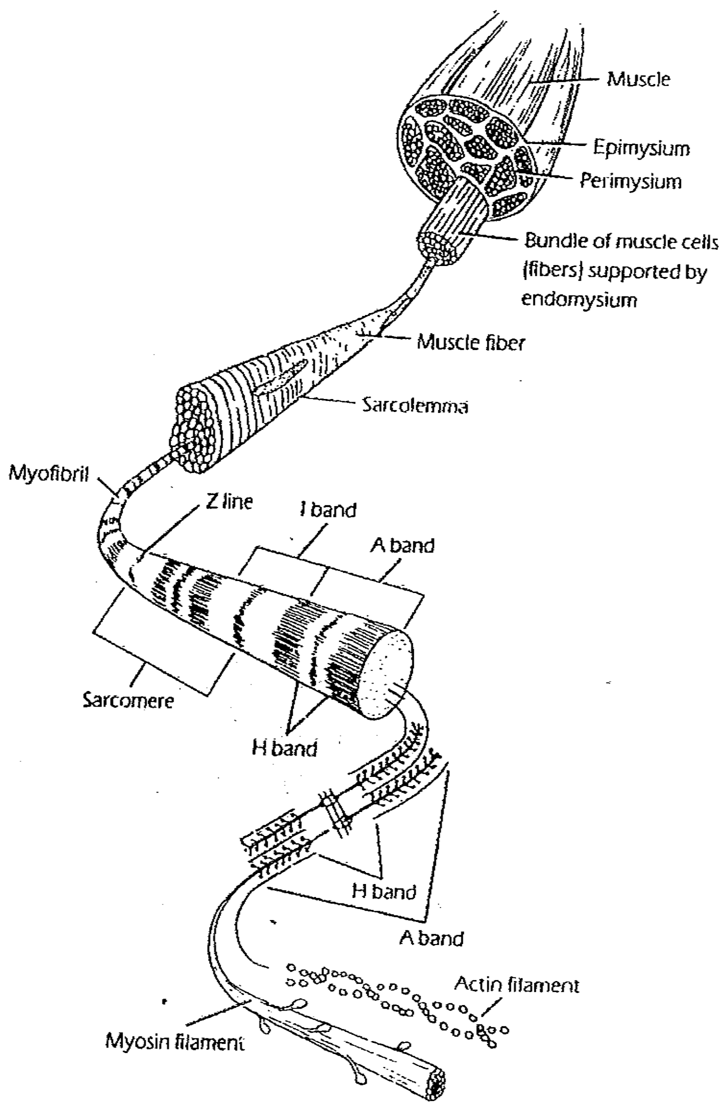
1) Potential space between ***Bone*** and ***Periorbita*** (periorbita can be easily separated from bone)
2) Space between ***muscle cone & intermuscular membrane*** and ***Tenon's capsule***
3) Tenosn's capsule
4) Space between ***orbital walls & the globe*** and ***orbital septum & tarsus & tarsal ligaments***

Methods to relieve orbital tension

1) Opening tenon's capsule (by conjunctival incision)
2) Division of one or more ocular muscle
3) Division of the lid (vertically & division of one or both Tarsal ligaments
4) Resection of part of the bony orbital wall.



Actin filaments
Z line
Myosin filament
Z line
I band
H zone
I band
A band



Muscle
Epimysium
Perimysium
Bundle of muscle cells (fibers) supported by endomysium
Muscle fiber
Sarcolemma
Myofibril
Z line
I band
A band
Sarcomere
H band
H band
A band
Actin filament
Myosin filament

Extrinisic Muscles

Structure.

Extra ocular muscle: The most highly differentiated of all striated muscles.

⇒ Derived from the ***mesenchyme*** in the region of the developing eye ball.

- *Mesoderm* → muscles fibers.
- *Neural crest cells* → Tendons & sheathes.

⇒ Large content of elastic & nerve fibers (in relation to size)

⇒ Consists of muscle fiber & C.T

1)Muscle fibers

- Diameter → 9-30 μm
- Each fiber
  - Surrounded by → **Sarcolema**
  - Contains → **Cytoplasm** + numerous **myofibrils** + **Multinuclei** (peripherally situated)
- Types :

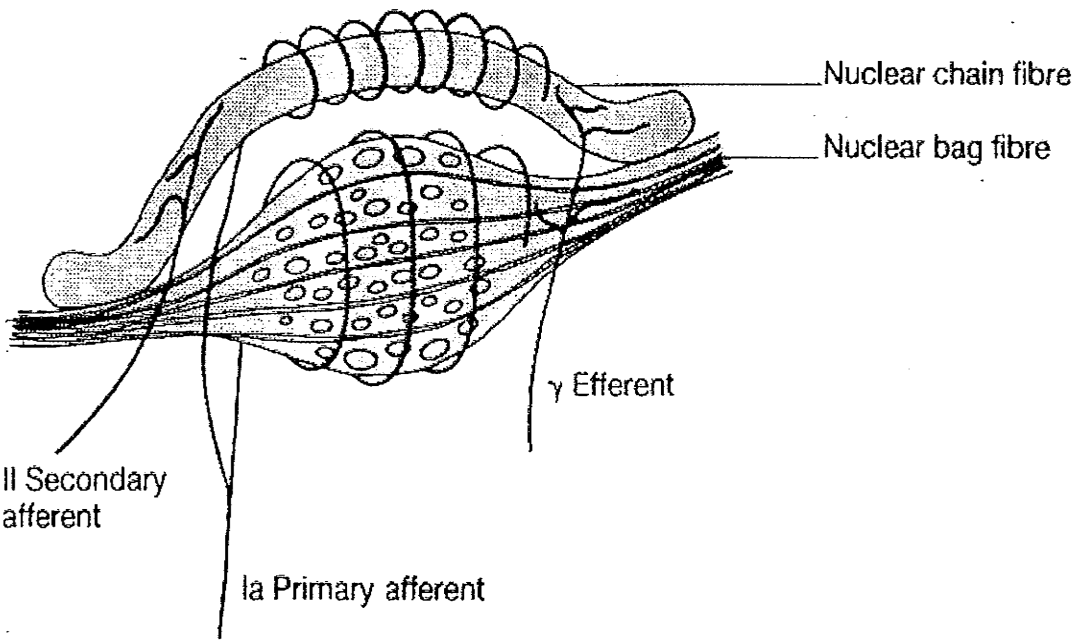
	Slow fibers	Fast fibers
Responsible for	*graded contracture* → Long duration	*Rapid action* → Short duration
Thickness	***Thin***	***Thick***
number	*Less* numerous	*More* numerous
Site	On the ***exterior*** surface	In the ***central mass*** of the muscle
Correspond to	*red* muscle fibers, which contain a high content of mitochondria and oxidative enzymes.	*white* muscle fibers, which contain a high content of glycogen and glycolytic enzymes.
Innervated by	*grape-like* motor nerve endings	*plaque-like* motor nerve endings

2)Connective tissue

Endomysium	Perimysium	Epimysium
C.T surrounding the ***individual*** fiber	C.T septa surrounding ***group*** of muscle fibers	C.T surrounds the ***whole*** muscle
Contain large amount of *elastic* tissue arranged longitudinally	Contain: • Large *elastic* fibers • *Vessles* & *nerves* • C.T *cells*	It is continuous with the Perimysium and with the sheath.

Sheaths of the muscle:

- From the origin for 2 cm ⇒ **Thin & Transparent.**
- From this till the globe ⇒ **Thick & Opaque.**
- Made of 2 layers → ***Outer circular*** fibers + ***Inner Longitudinal*** fibers

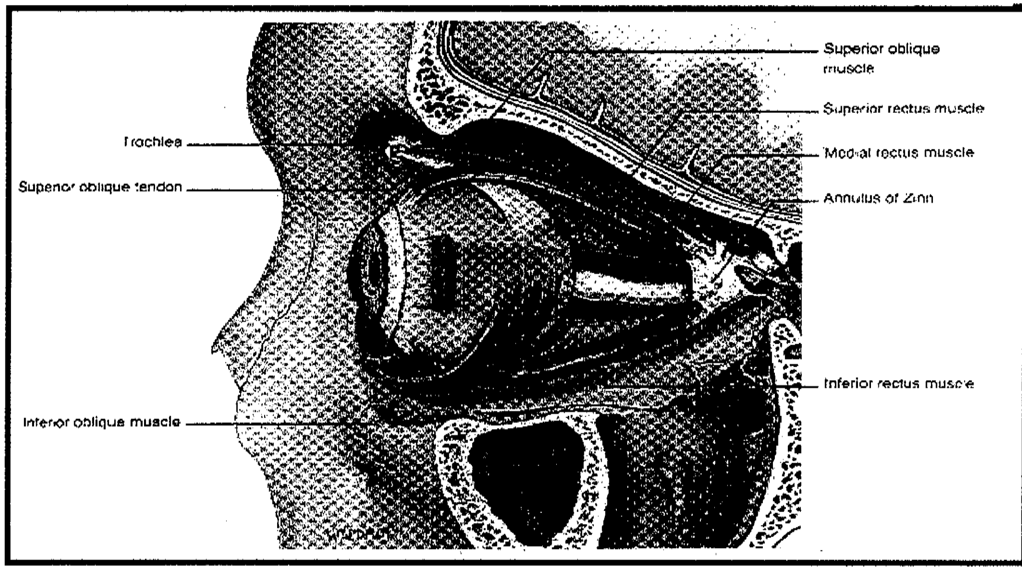

Nuclear chain fibre
Nuclear bag fibre
γ Efferent
II Secondary afferent
Ia Primary afferent

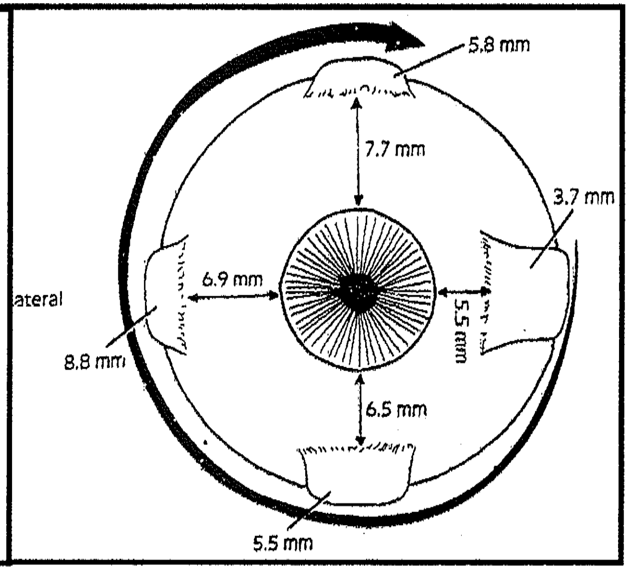
Tendons:

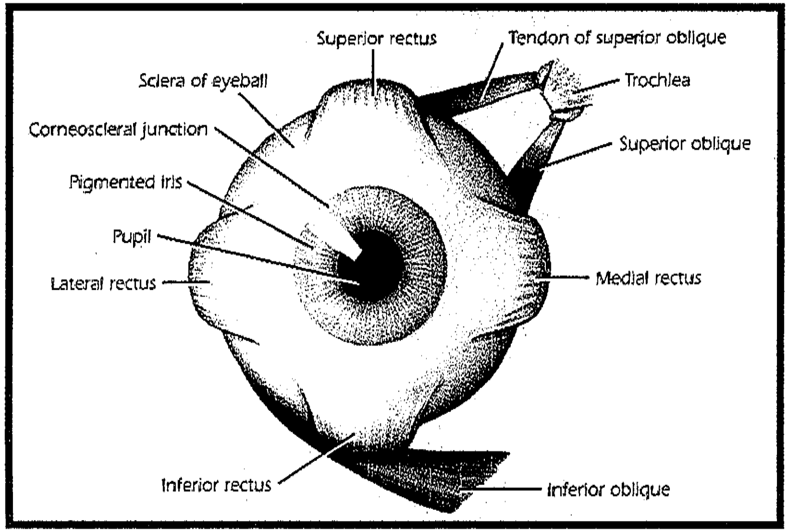
- Made of **Collagen & thick elastic** fibers **arranged parallel** to each other and to the muscle axis ⇒ ***Glistening silky appearance*** (unlike the dull white sclera cause of irregular arrangement of its collagenous fibers)
- The tendon enters the superficial scleral layer → becomes indistinguishable from it
  - Some slips of the muscle leave the main tendon → inserted further back (missed in tenotomy)
  - Only cessation of the thick elastic fibers marks the end of the tendon.

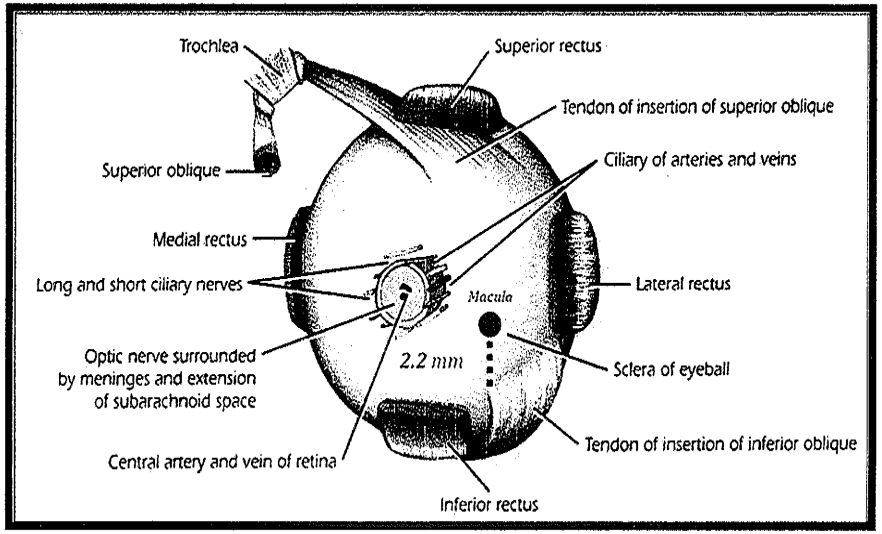
Proprioceptive nerve endings:

- The muscle spindles
  1) **Smaller** & more delicate than those in other somatic muscles.
  2) More **numerous**
  3) Consist of a ***Torpedo shaped fibrous capsule*** enclosing ***Intrafusal fibers***
     - The fibrous capsule ⇒ Thin & consists of 2-3 layers
     - The intrafusal fibers ⇒
       a) 2 types ⇒ ***Nuclear chain & nuclear bag.***
       b) 2 differences from extrafusal fibers :
          → Central nuclei.
          → Smaller diameter.
       c) May end in 2 ways :
          → At the termination of the capsule.
          → Continue outside with extrafusal fibers.


Superior oblique muscle
Superior rectus muscle
Medial rectus muscle
Annulus of Zinn
Trochlea
Superior oblique tendon
Inferior rectus muscle
Inferior oblique muscle

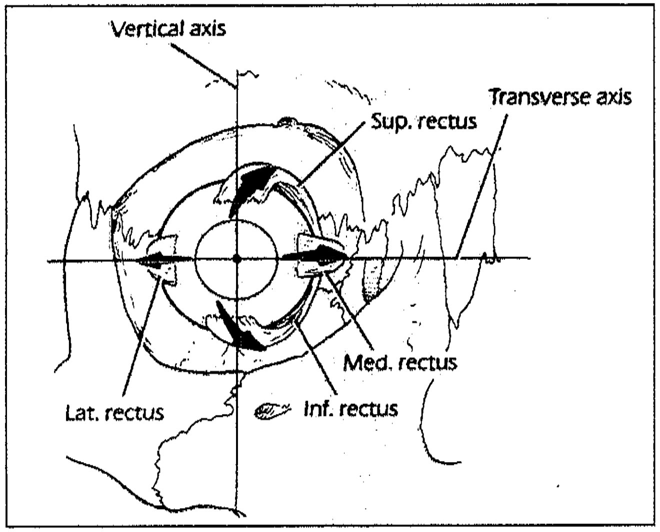

5.8 mm
7.7 mm
3.7 mm
6.9 mm
5.5 mm
8.8 mm
6.5 mm
5.5 mm
ateral

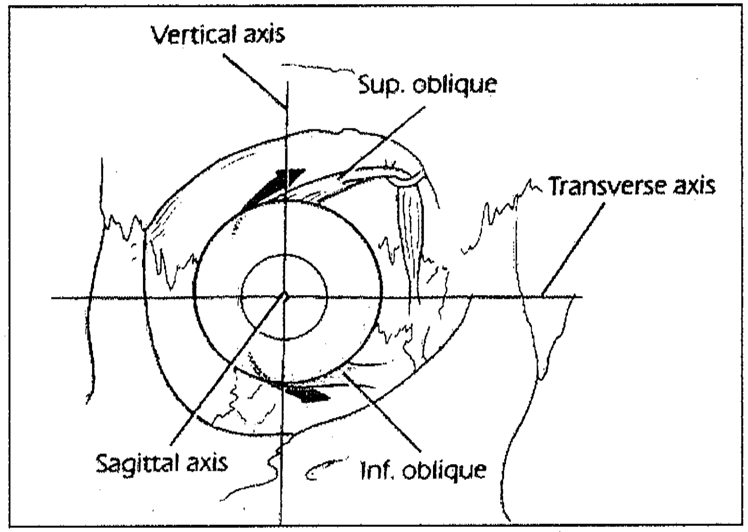

Superior rectus
Tendon of superior oblique
Sclera of eyeball
Trochlea
Corneoscleral junction
Superior oblique
Pigmented iris
Pupil
Lateral rectus
Medial rectus
Inferior rectus
Inferior oblique

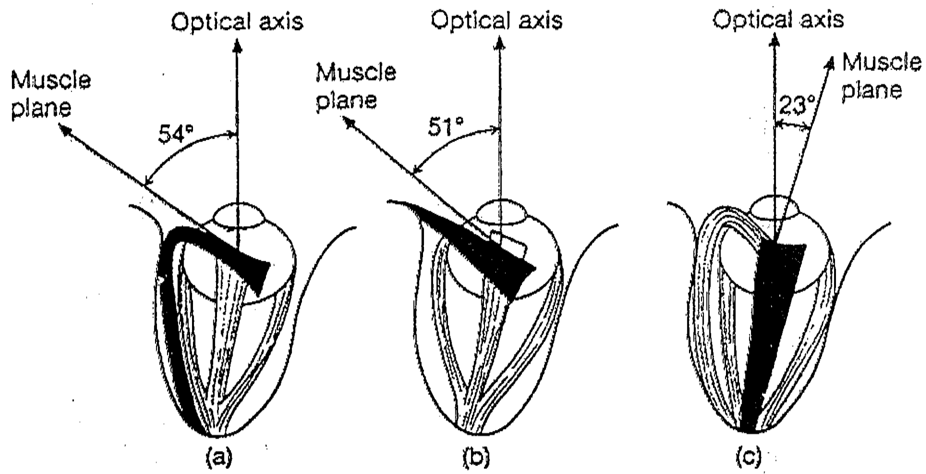

Trochlea
Superior rectus
Tendon of insertion of superior oblique
Superior oblique
Ciliary of arteries and veins
Medial rectus
Long and short ciliary nerves
Lateral rectus
Macula
Optic nerve surrounded by meninges and extension of subarachnoid space
2.2 mm
Sclera of eyeball
Tendon of insertion of inferior oblique
Central artery and vein of retina
Inferior rectus

Extraocular Muscles

	Origin	Course	Insertion In the sclera (after piercing the tenon)	N. Supply	Action
Superior Rectus	Upper part of the Common tendinous ring. (tendon of **Lookwood**) + **Sheath of optic nerve** ↓ (Pain with ocular movement in retrobulbar neuritis)	***Passes forward & laterally*** (form an angle of 23° with the optical axis) Superiorly it is beneath the levator palpebrae superioris muscle throughout its course	7.7 mm from limbus **5.8** mm tendon length **42** mm muscle length *Line of insertion* **10.8** mm **oblique** **convex forwards**	**Sup. division of occulomotor n.** (enters bulbar surface at the junction of the middle & posterior **1/3**)	**Elevation** (↑ in abduction) (absent in adduction.) **Adduction** (Aids in adduction, When the eye is turned medially) **Intorsion**. (↑ in adduction)
Inferior Rectus	Inferior part of the Common tendinous ring. (tendon of **Zinn**)	***Passes forward & laterally*** (form an angle of 23° with the optical axis)	**6.5** mm from limbus **5.5** mm tendon sheath **40** mm muscle length *Line of insertion* 9.8 mm convex forwards ***capsulo- palpebral ligament*** facial expansion of inf. rectus sheath attaches it to the lower border of lower tarsus. **Analogous to levator aponeurosis**	**Inf. division of occulomotor n.** (enters bulbar surface at the junction of the middle & posterior **1/3**)	**Depression.** (↑ in abduction) (absent in adduction.) **Adduction.** (Aids in adduction, When the eye is turned medially) **Extorsion**. (↑ in adduction) **retractor of the lower lid** (Through fibrous tarsal & subconjunctival attachments)
Medial Rectus	Medial part of the Common tendinous ring. + **Sheath of optic nerve**	Runs forward along the medial wall of the orbit (The largest EOM in bulk)	**5.5** mm from limbus **3.7** mm tendon sheath **40** mm muscle length *Line of insertion* **10.3** mm **Straight**	**Inf. division of occulomotor n.** (enters bulbar surface at the junction of the middle & posterior **1/3**)	Pure **Adduction**. (medial rotation)
Lateral Rectus	Lateral part of the Common tendinous ring. (by 2 heads).	Runs forward along the lateral wall of the orbit, Passing over the insertion of inferior oblique muscle	**6.9** mm from limbus **8.8** mm tendon sheath **48** mm muscle length *Line of insertion* **9.3** mm **Straight** or slightly **convex forwards.**	**Abducent n.** (enters bulbar surface just behind its middle)	Pure **Abduction**. (lateral rotation)

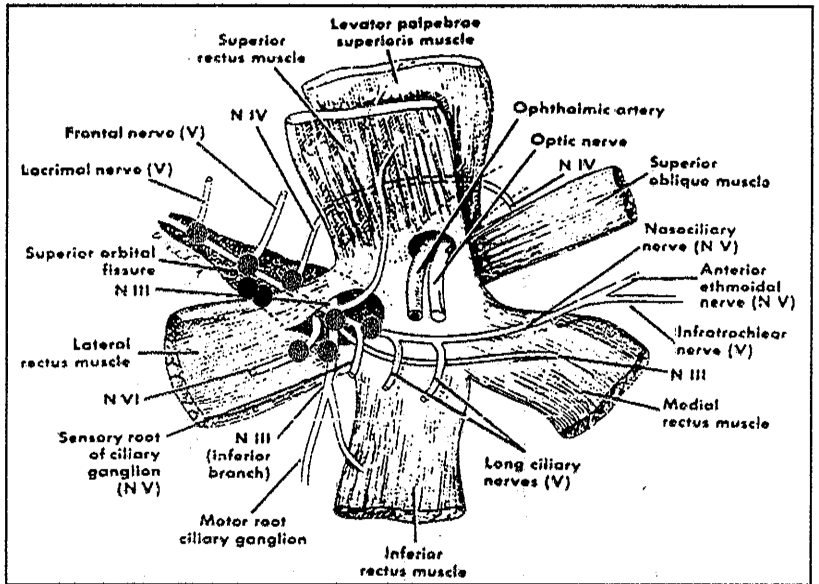


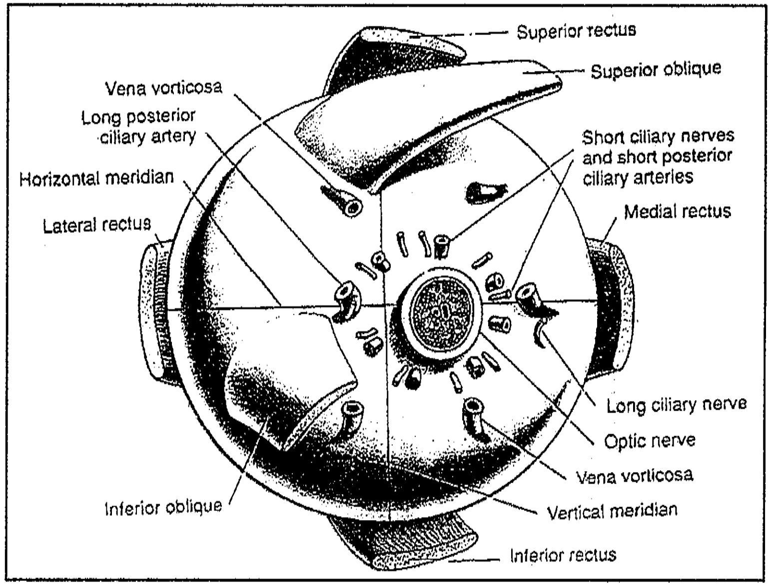


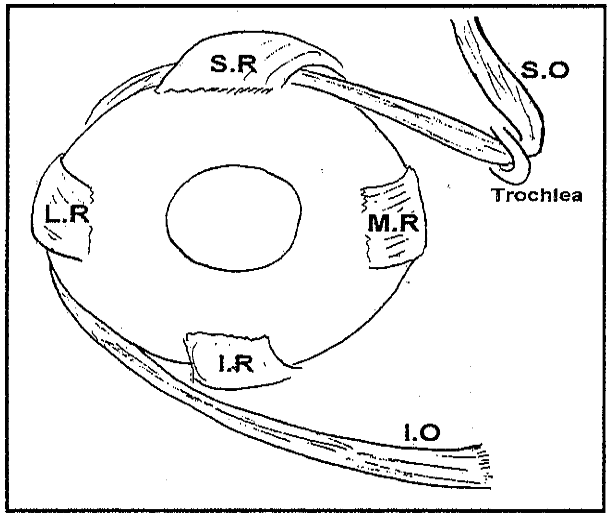


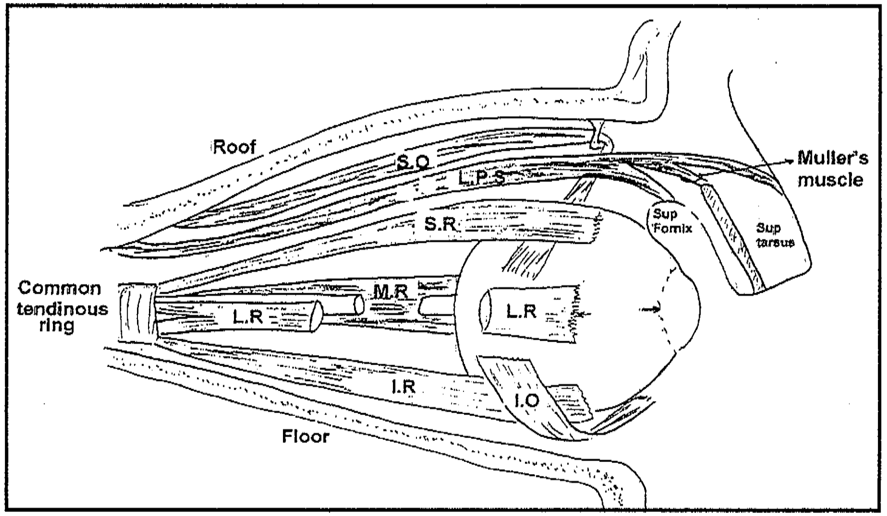
Rt SO (from above) **Lt IO** (from below) **Rt SR** (from above)

	Origin	Course & Insertion	N. Supply	Action
levator palpebre superiosis	**Back of the roof** (periosteal covering of the lesser wing of sphenoid) **just in front of the optic canal.** Its origin blends with that of the **SR** muscle below & the **SO** muscle medially	It runs forward beneath the roof of the orbit to a point about 1 cm behind the orbital septum, where it expands into an ***aponeurosis***, which passes through the orbital septum → inserted in : 1) The **skin** of the eyelid → form the superior palpebral furrow. 2) The anterior surface of the **upper tarsus.** 3) The **medial and lateral palpebral ligaments** 4) **Sup. fornix** 5) ***Muller's m.*** (superior tarsal muscle) ⇒ arise from its under surface → inserted in upper border of tarsus (involuntary and sympathetically supplied).	**Sup. division of oculomotor n.** (*passes through* or *turn around* the medial border of the underlying SR to reach the inferior surface of levator muscle **Sympathetic** (From carotid plexus → join oculomotor n.)	**Elevates** upper lid & sup. Fornix **Deepens** upper palpebral crease
Superior Oblique	**Back of the roof** (periosteal covering of the lesser wing of sphenoid) **antero-medial to the optic canal.**	**Direct muscular portion** → It passes forward in the angle between the roof and the medial wall of the orbit to the trochlea →The trochlea is a synovial-lined fibrocartilage U shaped sling attached to the trochlear spine of the medial aspect of the frontal bone about 4 millimeters behind the superior orbital margin. **Reflected tendineous portion** → begins about 10 mm, behind the trochlea → From the trochlea the tendon passes Backward, Downward & laterally (making an angle of **55°** with the optical axis) → Pierce the tenon's capsule → pass beneath the superior rectus ms to be inserted into the ***posterior, upper, lateral*** quadrant of sclera. → The tendon becomes flatter and wider (fan shaped) as it approaches the medial margin of the superior rectus Line of insertion **10.7** mm **Convex backwards and laterally** - The Longest, thinnest & most rounded EOM. - The anterior end lies at the same meridian as the temporal end of SR	**Trochlear n.** Enters the muscle **superiorly & near its lateral border** After dividing into 3-4 branches	**Depression** (↑ in adduction) (absent in abduction) **Intorsion** (↑ in abduction) **Abduction** (Aids in abduction in the straight ahead position)
Inferior Oblique	**Floor of orbit** (periosteum covering the orbital plate of maxilla) **lateral to the lacrimal groove.** (Few fibers take origin from lacrimal fascia)	It passes laterally and backwards, ♣ **below the inf. Rectus** (in a tunnel in the fascia that envelops the inf. Rectus ms) (making an angle of **50°** with the optical axis) then ♣ **deep to the lat. Rectus** to be inserted in the ***posterior, lower, lateral*** quadrant *of* the sclera. Line of insertion **9.4** mm **oblique** **convex upwards**	**Inf. division of oculomotor n.** (enters its bulbar surface just after the muscle has passed to the lateral side of the inferior rectus muscle)	**Elevation** (↑ in adduction) (absent in abduction) **Extorsion** (↑ in abduction) **Abduction** (Aids in abduction In laterally rotated muscle)
	(The only EOM to originate in front of the equator)	- It has a very short tendon (even none) - The nasal end of insertion is 5.5 from optic nerve → very near to the macula (2.2 mm) - The temporal end lies at the same meridian as the lower end of insertion of lateral rectus (surgical imp.)		


Levator palpebrae superioris muscle
Superior rectus muscle
N IV
Frontal nerve (V)
Lacrimal nerve (V)
Superior orbital fissure
N III
Lateral rectus muscle
N VI
Sensory root of ciliary ganglion (N V)
N III (inferior branch)
Motor root ciliary ganglion
Inferior rectus muscle
Ophthalmic artery
Optic nerve
N IV
Superior oblique muscle
Nasociliary nerve (N V)
Anterior ethmoidal nerve (N V)
Infratrochlear nerve (V)
N III
Medial rectus muscle
Long ciliary nerves (V)


Superior rectus
Superior oblique
Vena vorticosa
Long posterior ciliary artery
Horizontal meridian
Lateral rectus
Short ciliary nerves and short posterior ciliary arteries
Medial rectus
Long ciliary nerve
Optic nerve
Vena vorticosa
Vertical meridian
Inferior oblique
Inferior rectus


S.R
S.O
Trochlea
L.R
M.R
I.R
I.O


Roof
S.O
L.P.S
S.R
Muller's muscle
Sup Fornix
Sup tarsus
Common tendinous ring
M.R
L.R
L.R
I.R
I.O
Floor

Relations of Extraocular muscles

<table>
<tr><th></th><th>Superior rectus</th><th>Inferior rectus</th><th>Medial rectus</th><th>Lateral rectus</th><th>L.P.S</th><th>Sup. oblique</th><th>Inf. oblique</th></tr>
<tr><td>Superior</td><td>- Orbital roof
- LPS

- Frontal n.
- Trochlear n.
- Supraorbital vs.</td><td>Optic nerve
(separated by fat)

Inferior division of 3rd

Inferior ophthalmic v.</td><td><u>Superior oblique</u>
+
in between

- Ophthalmic a.

- Ethmoidal n + vs
(Ant & Post)

- Infratrochlear n.</td><td rowspan="4"><u>AT THE APEX</u>
Structures passing <u>between</u> the 2 heads
(from up → down)
= within the cone of ms
= within annulus of Zinn
= through oculomotor F.
(1) superior div. of 3rd
(2) Nasociliary n + sympathetic branch
(3) Inferior div. of 3rd
(4) Abducent n.
(5) Inf. Ophthalmic v.

Structures passing <u>above</u> upper head
(1) Trochlear n.
(2) Frontal n.
(3) Lacrimal n.
(4) Rec meningeal a.
(5) Sup. Ophthalmic v.

<u>IN THE ORBIT</u>
Above
(1) Lacrimal a.
(2) Lacrimal n.
(3) Lacrimal gland
Below
(1) Orbital floor
(2) Inf. oblique tendon
Lateral
(1) Post. → Periosteum
(2) Middle → orbital fat
(3) Ant. → Lacrimal gl.
Medial
(1) Bet. LR & Optic n →
→ 6th +3rd nerves
→ Ciliary ganglion
→ Ophthalmic a.
→ Nasociliary n.
(2) Bet. LR & IR →
→ N. to inf. oblique</td><td rowspan="4"><u>Above</u>
(1) Frontal n.
(2) Trochlear n.
(3) Supraorbital vessels.

<u>Below</u>
Sup. Rectus
(its medial part)
Optic nerve
Globe

<u>In front of the aponeurosis</u>
- Retroseptal fat
- Orbital septum
- Orbicularis ms.

<u>Behind the aponeurosis</u>
peripheral arterial arcade

Palpebral portion of lacrimal gland.</td><td>Orbital roof</td><td><u>Upper surface</u>
faces

<u>First</u>
Orbital fat

<u>Then</u>
Inf. Rectus

<u>Finally</u>
The globe</td></tr>
<tr><td>Inferior</td><td>- Optic nerve
(separated by fat)

- Ophthalmic a.
- Nasociliary n.

- Sup. oblique
(reflected tendon)</td><td>Orbital Floor
(bounds maxillary sinus)

Infraorbital nerves & vessels.
(in their canal)

Inferior oblique
(anteriorly, both sheathes unite)</td><td>Orbital Floor</td><td><u>Ophthalmic a.</u>
(And its branches)

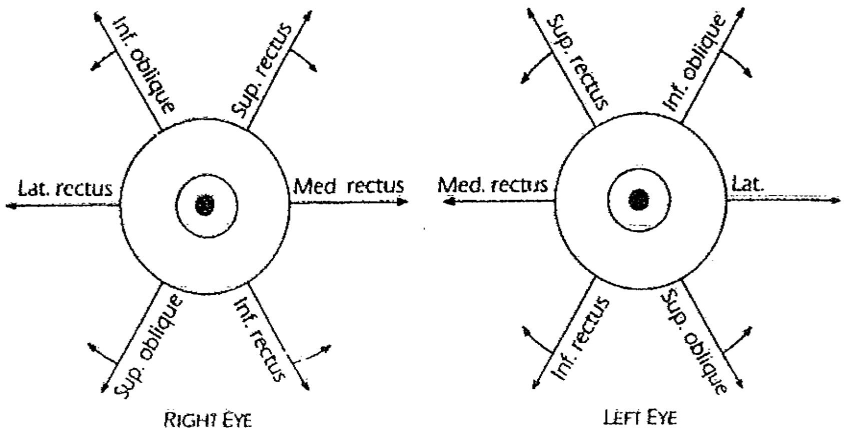
<u>Nasociliary n.</u></td><td><u>Lower surface</u>
faces

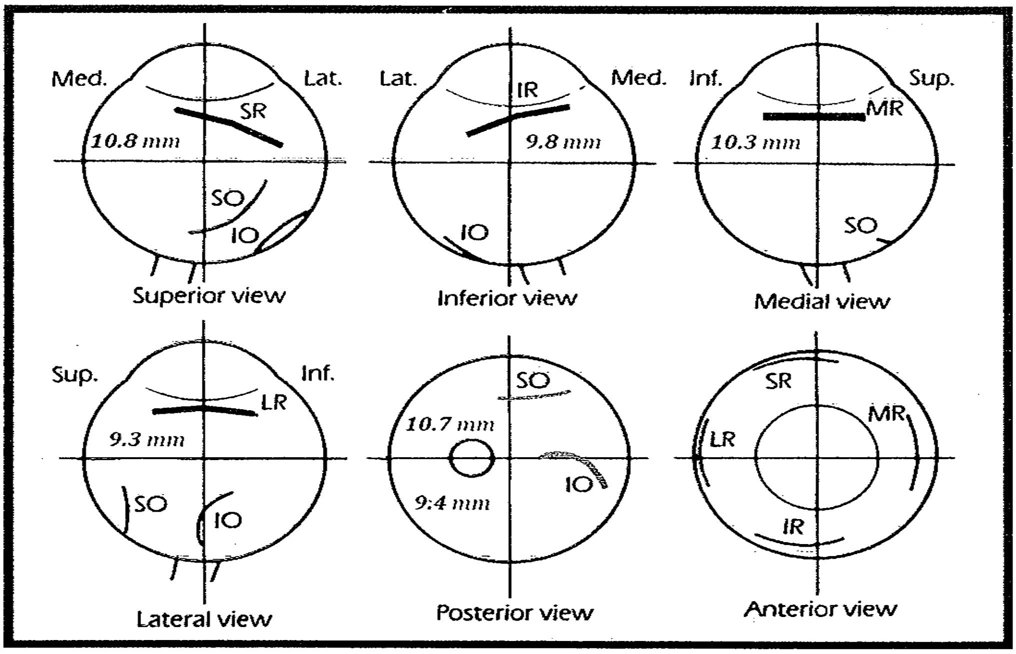
<u>First</u>
Orbital floor

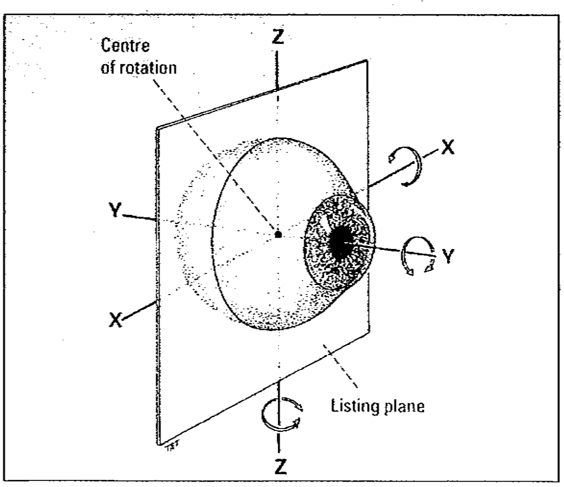
<u>Then</u>
Orbital fat

<u>Finally</u>
(near its insertion when this surface faces laterally)
it is covered by
Lateral rectus
&
Tenon capsule</td></tr>
<tr><td>Lateral</td><td>• Lacrimal a.
• Lacrimal n.</td><td>nerve to inferior oblique</td><td>Central orbital fat</td><td><u>Supratrochlear nerve</u>
(Lateral to the trochlea)</td><td></td></tr>
<tr><td>Medial</td><td><u>Ophthalmic a.</u>

<u>Nasociliary n.</u></td><td></td><td>Orbital plate of ethmoid (bounds ethmoidal sinus)</td><td></td><td></td></tr>
</table>


Inf. oblique
Sup. rectus
Lat. rectus
Med rectus
Sup. oblique
Inf. rectus
RIGHT EYE
Sup. rectus
Inf. oblique
Med. rectus
Lat.
Inf. rectus
Sup. oblique
LEFT EYE


Med.
Lat.
SR
10.8 mm
SO
IO
Superior view
Lat.
Med.
IR
9.8 mm
IO
Inferior view
Inf.
Sup.
MR
10.3 mm
SO
Medial view
Sup.
Inf.
LR
9.3 mm
SO
IO
Lateral view
SO
10.7 mm
IO
9.4 mm
Posterior view
SR
MR
LR
IR
Anterior view


Centre
of rotation
Z
X
Y
Y
X
Listing plane
Z

General considerations

- Blood supply of EOM:
  - **Medial muscular** branch of ophthalmic (or lacrimal) → **IR, IO, MR**
    N.B. IO takes also from infra-orbital a.
  - **Lateral muscular** branch of ophthalmic (or lacrimal) → **LR, SR, SO, LPS**
- All extraocular muscles are supplied by the ***oculomotor n.*** except the lat. rectus (by ***abducent n.)*** and sup. oblique (by ***trochlear n.).***
- All extraocular ms, originate behind the eye ball except the **inf. Oblique**.
- ***Recti*** muscles insert **in front of** the equator, while ***oblique*** muscles insert **behind** the equator.
- Obliques are **below** recti.
- All extraocular ms, are attached to the eye ball except the levator palpebrae superiosis.
- The medial rectus is the **strongest & largest** of the recti, the lateral rectus is the **longest**.
- Acting together, the 4 recti retract the eye ball while the 2 obliques protrude it.
- Lesion to levator palpebrae superiosis → **Ptosis**.
- While Muller's m. paralysis (as a part *of Horner's syndrome*) → **Partial ptosis**

Talking about any EOM ⇒ Origin + Course + Insertion + Nerve supply + Blood supply + Action + Structure + Relations

Recti	→ Adduction
Obliques	→ Abduction
Superiors	→ Intorsion
Inferiors	→ Extorsion

Eye movement

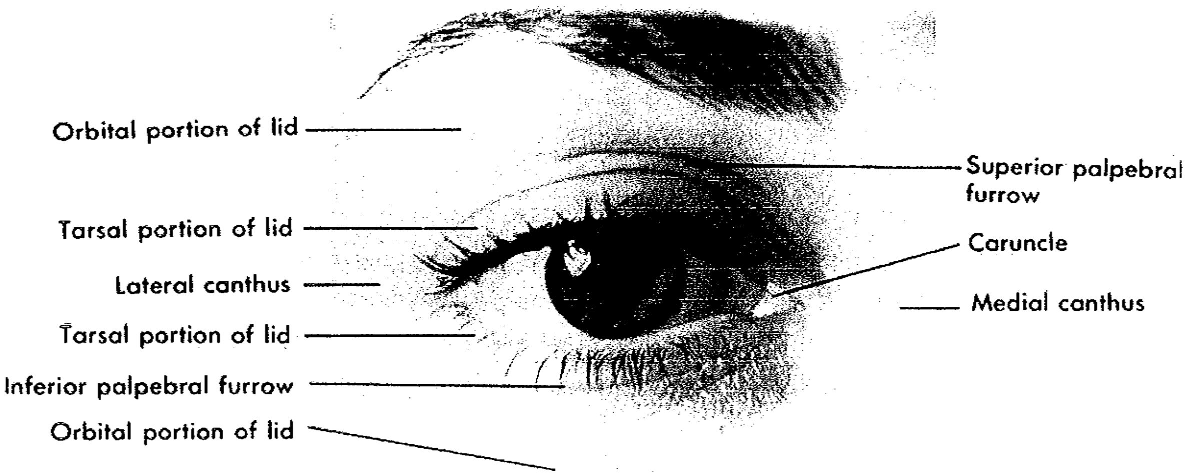
Uniocular movement **(Duction)**

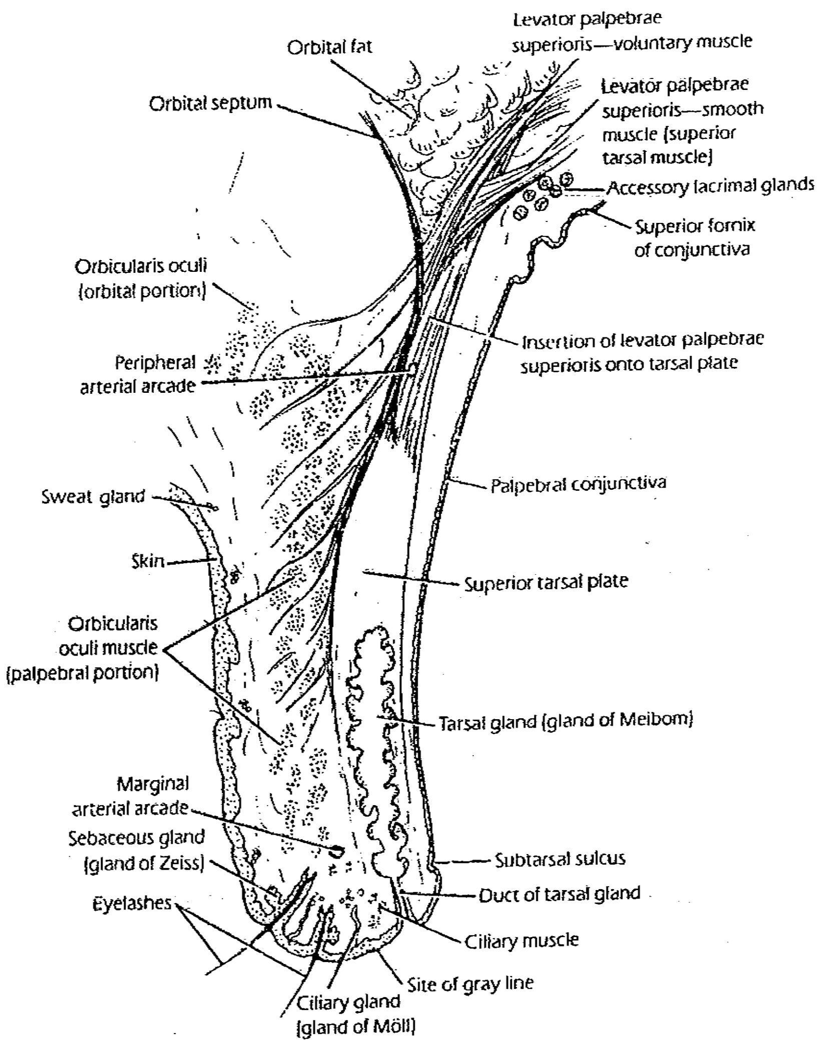
⇒ Around vertical axis → Adduction & Abduction
⇒ Around horizontal axis → Elevation & Depression
⇒ Around Antero-post axis → Intorsion & Extorsion.

Binocular movements

(1) **Versions**: ⇒ Simultaneous movement of both eyes in the same direction
→ Dextroversion
→ Levoversion
→ Supraversion
→ Infraversion
→ Dextrocycloversion
→ Levocycloversion

(2) **Vergences**: ⇒ Simultaneous movement of both eyes in opposite directions
→ Convergence
→ Divergence


Orbital portion of lid
Tarsal portion of lid
Lateral canthus
Tarsal portion of lid
Inferior palpebral furrow
Orbital portion of lid
Superior palpebral furrow
Caruncle
Medial canthus

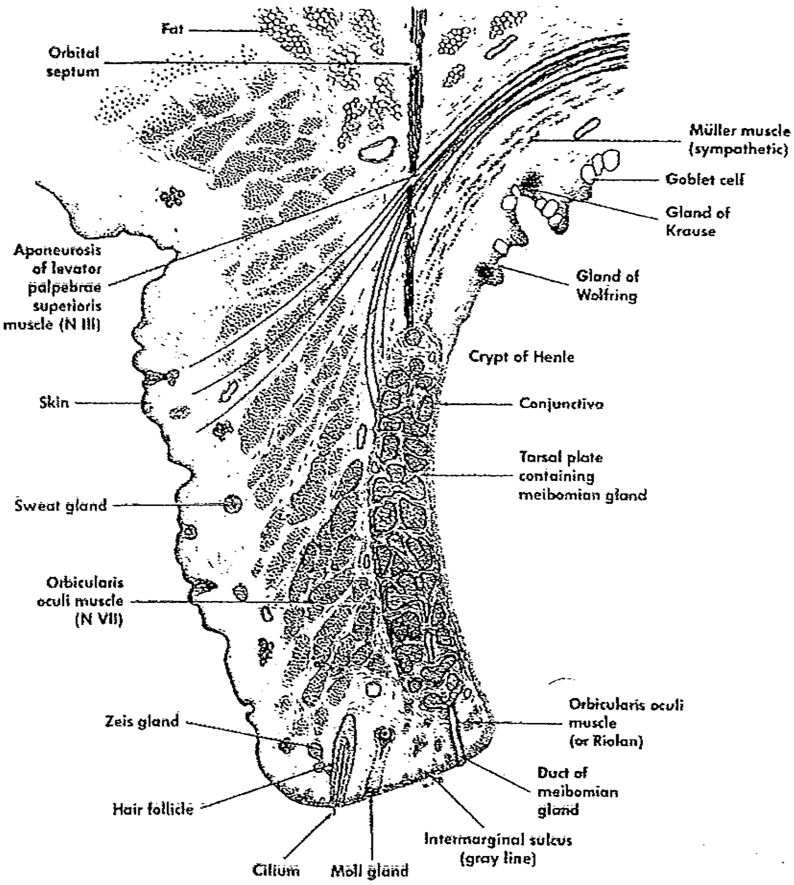

Levator palpebrae superioris—voluntary muscle
Orbital fat
Orbital septum
Levator palpebrae superioris—smooth muscle (superior tarsal muscle)
Accessory lacrimal glands
Superior fornix of conjunctiva
Orbicularis oculi (orbital portion)
Insertion of levator palpebrae superioris onto tarsal plate
Peripheral arterial arcade
Palpebral conjunctiva
Sweat gland
Skin
Superior tarsal plate
Orbicularis oculi muscle (palpebral portion)
Tarsal gland (gland of Meibom)
Marginal arterial arcade
Sebaceous gland (gland of Zeiss)
Subtarsal sulcus
Duct of tarsal gland
Eyelashes
Ciliary muscle
Site of gray line
Ciliary gland (gland of Möll)

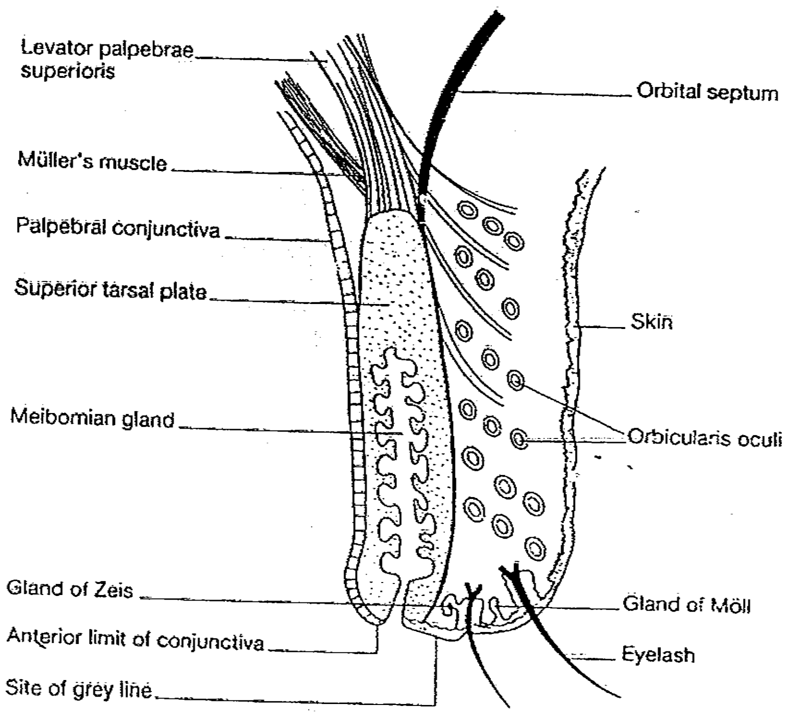
Eyelids

- **Definition:** are thin curtains of <u>skin</u>, <u>muscle</u>, <u>fibrous tissue</u>, & <u>mucous membrane</u> that
  - protect the eye from external irritation,
  - limit the amount of light entering the eye, &
  - distribute tears over the surface of the globe.

- **Gross:**
  - The upper eyelid is <u>limited</u> above by the eyebrow; the lower eyelid <u>merges</u> with the cheek.
  - Upper lid → covers 1/5 of upper part of cornea, while lower lid → is just touching the limbus
  - Both lids meet over the <u>inferior part</u> of the cornea on blinking.
  - Each eyelid is divided by a **<u>horizontal furrow (sulcus)</u>** into <u>orbital</u> & <u>tarsal</u> portion.
    - The **upper** furrow is formed by *<u>skin</u>* insertions of the *<u>levator palpebrae superioris</u>* muscle.
    - The **lower** furrow is formed by facial expansions between *<u>orbicularis</u>* *<u>oculi muscle</u>* & *<u>skin</u>*, it is poorly defined.
  - the **<u>palpebral fissure</u>**
    - Measures about **12** X **30** mm
    - <u>Laterally</u> the fissure forms a 60° angle; <u>medially</u> it is rounded.
    - Epicanthus: vertical skin fold hiding the caruncle. [notmal in <u>infants</u> (underdeveloped nasal ridge) & <u>orientals</u>]
    - ***In blacks and whites***
      - → the lateral canthus is about 2mm higher than the medial
      - → the fissure is widest at the junction of the inner ⅓ with the outer ⅔
      - → If epicanthus is present → the eyes appear to be deviated inward (pseudostrabismus)
    - ***In Orientals** (mongolians)*
      - → the lateral canthus is about 5mm higher.
      - → the fissure is widest at the junction of the inner ½ with the outer ½
      - → Epicanthus is present normally
  - **<u>The margin</u>** of each eyelid ⇒ **2** mm thick and **30** mm long.
  - ***<u>Papilla lacrimalis</u>*** a small eminence at a point 5 mm from the medial angle, which contains the punctum. divides the eyelid into 2 portions:

lacrimal portion	**ciliary portion**
medial **1/6**	lateral **5/6**
<u>rounded</u> edges	***<u>squared</u>*** edges (<u>anterior</u> border → rounded & <u>posterior</u> border → Sharp)
no tarsus no gland openings no cilia **Charachters of cilia** • Arranged into 2-3 rows • No. ≈ 150/75 • Grow in 10 weeks • Remain 20 weeks • Darker & dont go grey • No erector pili ms	o The ***<u>gray line</u>***, → divides the eyelid into an anterior layer containing muscle & skin and a posterior layer containing tarsus & conjunctiva. → The eyelashes originate anterior to the gray line, and the orifices of the tarsal glands open posterior to it. o The ***<u>white line</u>*** (the orifices of the meibomian glands.) → <u>Muco-cutaneous junction:</u> lies at the posterior margin of orifices of tarsal glands o The ***<u>eyelashes</u>*** (cilia) → Upper eyelid lashes curve upward & are more numerous & longer → Lower eyelid lashes curve downward. & are less numerous & shorter → <u>Sebaceous glands (of Zeis)</u> 2 glands open into the follicle of each cilium → Large <u>sweat glands (of Moll)</u> open into the follicles or directly onto the eyelid margin between the cilia.


Fat
Orbital septum
Aponeurosis of levator palpebrae superioris muscle (N III)
Skin
Sweat gland
Orbicularis oculi muscle (N VII)
Zeis gland
Hair follicle
Cilium
Möll gland
Müller muscle (sympathetic)
Goblet cell
Gland of Krause
Gland of Wolfring
Crypt of Henle
Conjunctiva
Tarsal plate containing meibomian gland
Orbicularis oculi muscle (or Riolan)
Duct of meibomian gland
Intermarginal sulcus (gray line)

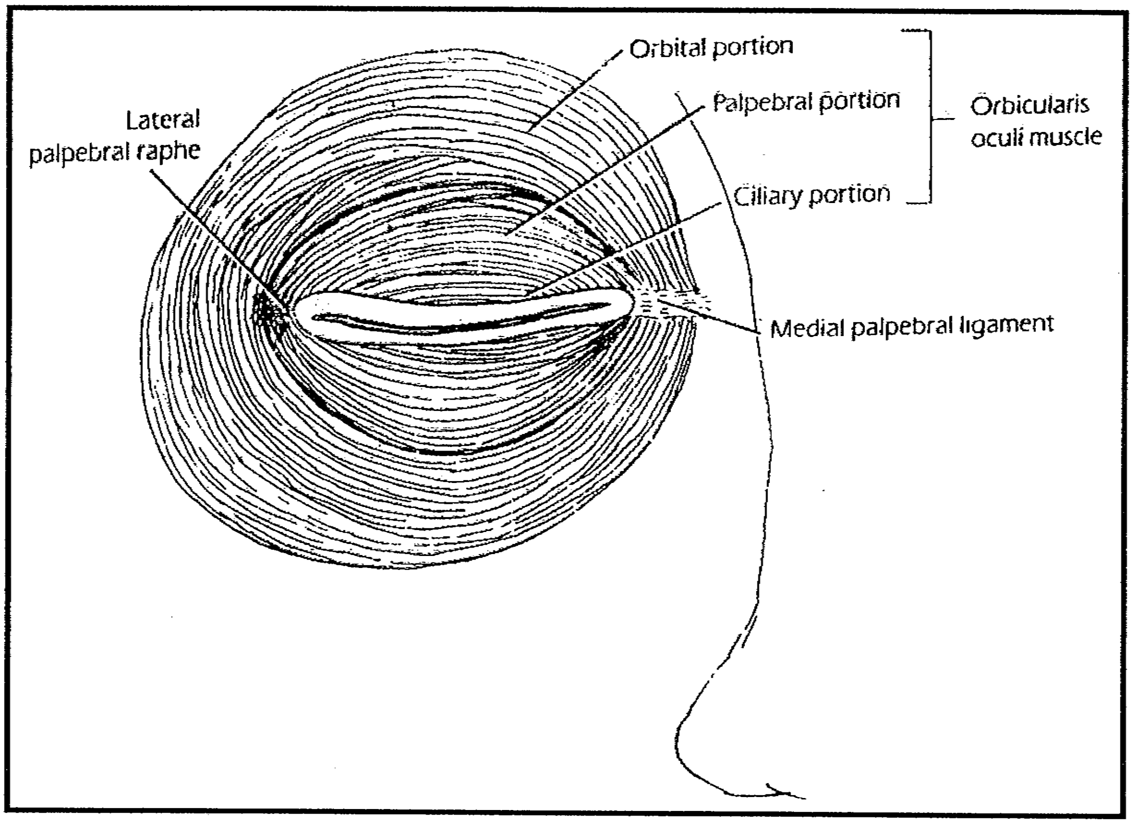

Levator palpebrae superioris
Müller's muscle
Palpebral conjunctiva
Superior tarsal plate
Meibomian gland
Gland of Zeis
Anterior limit of conjunctiva
Site of grey line
Orbital septum
Skin
Orbicularis oculi
Gland of Möll
Eyelash

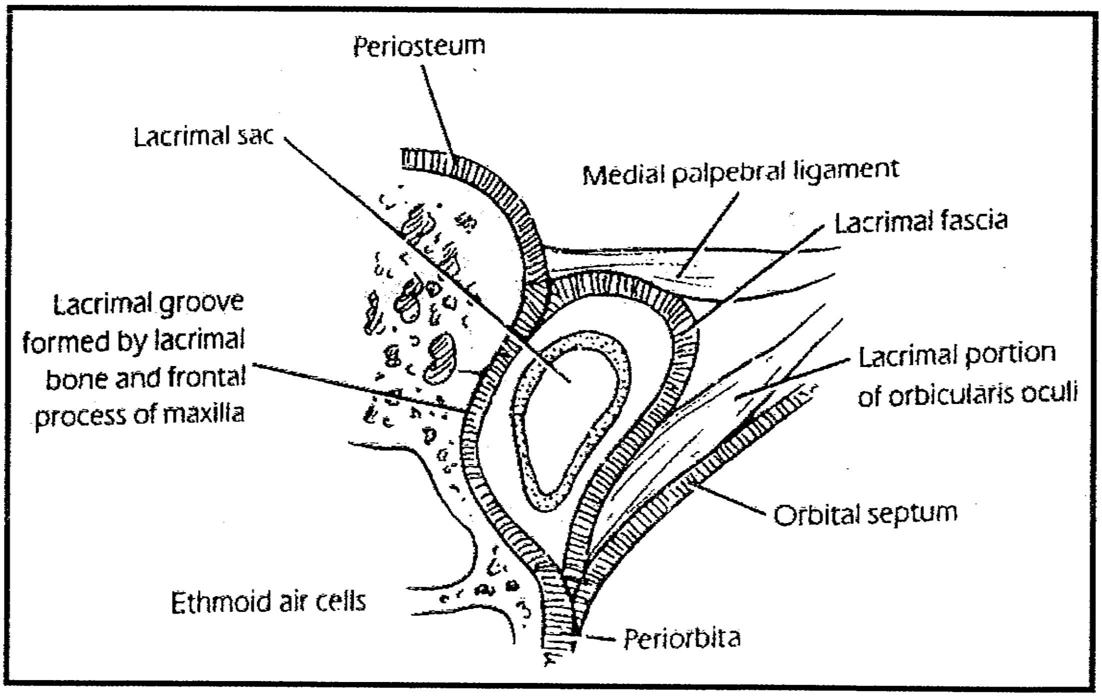
□ Structure:

- **Skin**
- **Muscles**
    - Orbicularis oculi (N VII)
        - → Orbital portion
        - → Palpebral portion
            - ⇒ Preseptal portion
            - ⇒ Pretarsal portion
    - Eyelid retractors
        - → Levator palpebrae superioris muscle (N III)
        - → Superior tarsal muscle (sympathetic)
        - → Inferior rectus muscle (N III)
        - → Inferior tarsal muscle (sympathetic)
- **Fibrous tissue**
    - Orbital septum (upper lid)
    - Tarsal plates
- **Conjunctiva**

The Skin

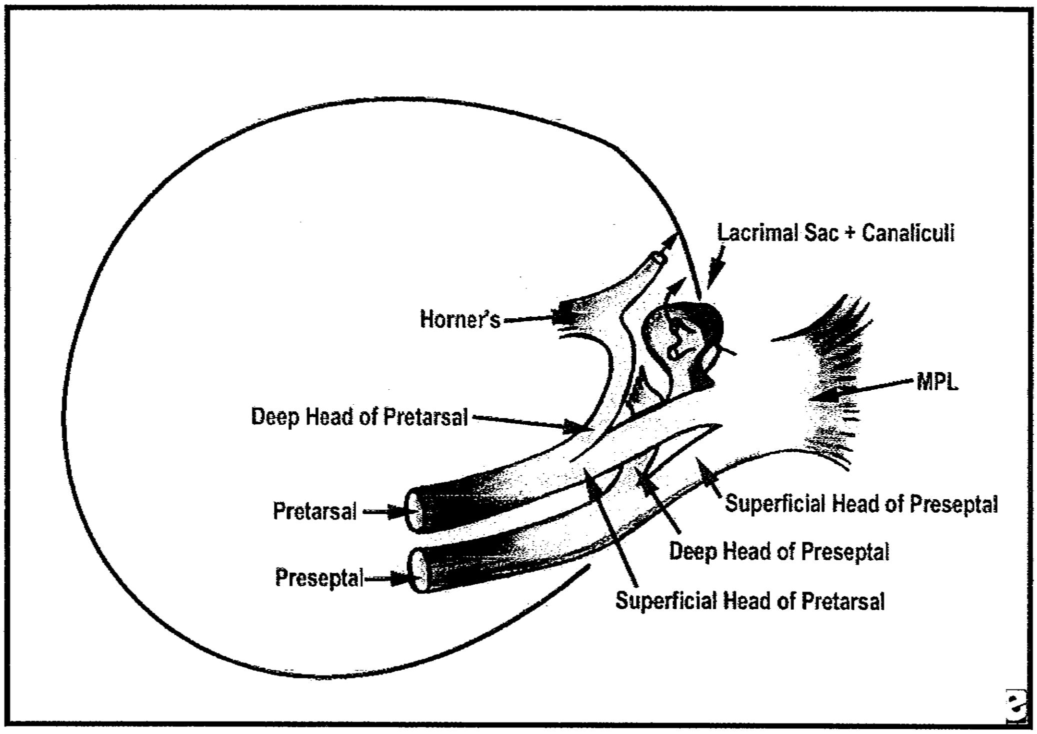
- The ***thinnest*** in the body → underlying blood vessels may appear as dark blue channels.
- *No fat* in the SC areolar C.T (hypodermis) → easily lifted from the muscle layer → **(1)** easily wrinkeld & thrown into folds. **(2)** easily distended by blood or edema.
- It is ***elastic*** → easily distended by blood or edema → but recoils rapidly
- Formed of *Epidermis*, *Dermis* (contains large melanin pigment cells which may be wandering → change in eyelid colour in diferent states of health) & *hypodermis*

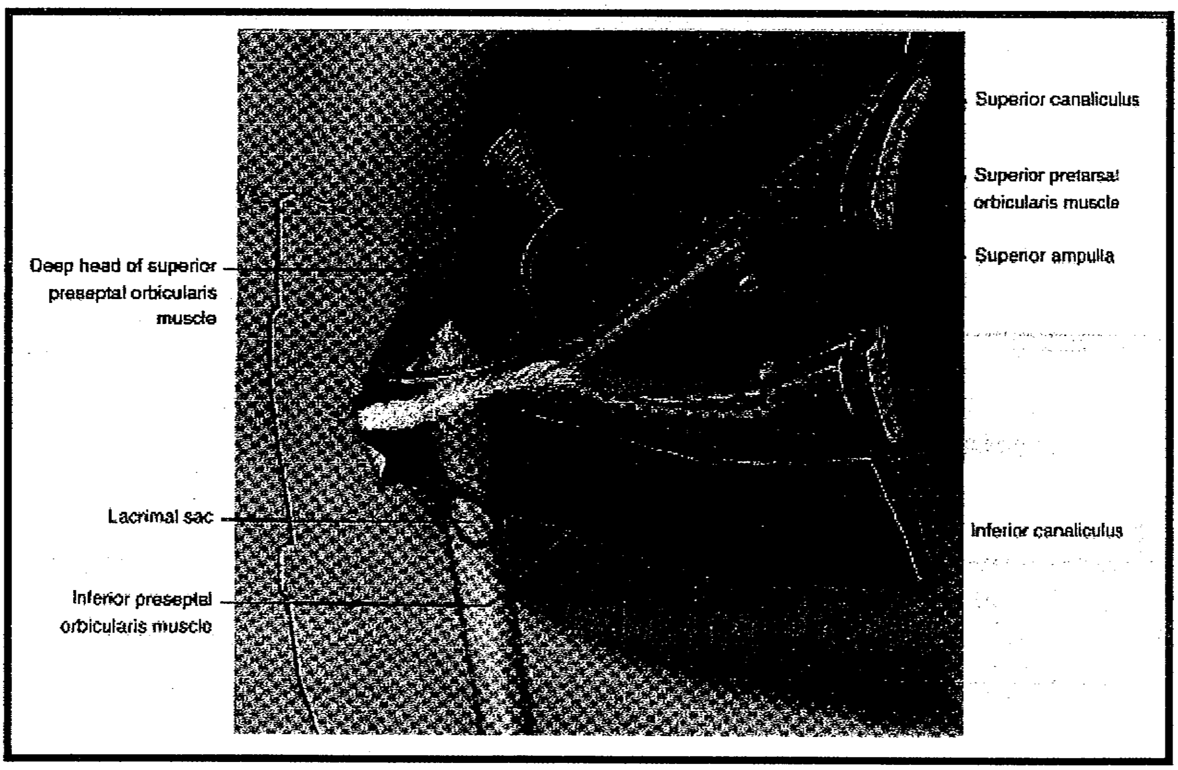

Orbital portion
Palpebral portion
Ciliary portion
Orbicularis oculi muscle
Lateral palpebral raphe
Medial palpebral ligament


Periosteum
Lacrimal sac
Medial palpebral ligament
Lacrimal fascia
Lacrimal groove formed by lacrimal bone and frontal process of maxilla
Lacrimal portion of orbicularis oculi
Orbital septum
Ethmoid air cells
Periorbita

Orbicularis Oculi muscle

- **Development**: From mesenchyme of the 2nd Branchial arch
- **Description**:
  - It is the sphincter of the eyelids.
  - A thin oval sheet of striated muscle composed of concentric layers that surround the palpebral fissure.
  - Parts: ***Orbital*** + ***Palpebral*** (preseptal + Pretarsal + Pars ciliaris + Pars lacrimalis)
- **Parts**:
  - ***Orbital part*** (deep & peripheral)
    - Origin: from the ***medial margin of the orbit*** and the ***anterior surfce of the medial palpebral ligament.***
    - Course: It runs concentrically around the globe
    - Insertion: into the ***periorbita of the superior and inferior orbital margin*** and into the ***lateral palpebral ligament.***
    - Relations:
      - ⇒ Upward → Spreads to the forehead, covers the corugator, enter in eye brow formation
      - ⇒ Downward → Spreads to the cheek, covers zygomatic bone & origin of levator labii
      - ⇒ Lateral → Spreads to the temple, covers the anterior part of temporal fascia
      - ⇒ Anterior → Separated from the skin by a layer of fat (to which it is adherent → acts on skin)
        - (1) **Musculus super-ciliaris (Merkel)** → upper medial fibers → depress medial end of eye brow
        - (2) **Musculus Malaris (Henle)** → lower fibers → attached to the skin of check
    - Action: ***Voluntary forcible closure*** of the eyelids
  - ***Palpebral part*** (superficial & central)
    - Origin:
      - ⇒ Deep heads ⇒ from the ***posterior lacrimal crest.***
      - ⇒ Superficial heads ⇒ from the ***medial palpebral ligament***
    - Insertion:
      - (1) Preseptal parts ⇒ Join to form the ***lateral palpebral raphae*** → inserts into the fascia investing the orbital muscle in the zygomatic region
      - (2) Pretarsal parts ⇒ ***Lateral canthal ligament*** → inserts into the lateral orbital tubercle (deep to the lateral palpebral raphae)
    - Relations:
      - ⇒ **Anterior** → Subcutaneous areolar CT (no fat) + Skin
      - ⇒ **Posterior** → Submuscular areolar C.T (contains blood vessels, nerves & fibers of levator with some of them penetrating the orbicularis ms to be inserted into the skin) + Orbital septum (preseptal) or Tarsus (pretarsal)
    - Action: ***Involuntary blinking***
      1) Spontaneous (Rhythmic)
      2) Reflex blinking in response to any danger or loud voice


Lacrimal Sac + Canaliculi
Horner's
MPL
Deep Head of Pretarsal
Pretarsal
Superficial Head of Preseptal
Deep Head of Preseptal
Preseptal
Superficial Head of Pretarsal


Superior canaliculus
Superior pretarsal orbicularis muscle
Superior ampulla
Deep head of superior preseptal orbicularis muscle
Lacrimal sac
Inferior canaliculus
Inferior preseptal orbicularis muscle

- ***Ciliary part (pars ciliaris) = Riolan's muscle***
  - In the whole thickness of lid margin,
  - Traversed by hair follicles & glands
  - Part of it is superficial to tarsus & part is deep

- ***Lacrimal part (pars lacrimalis) = Horner's muscle***
  - **Origin** → upper ½ of posterior lacrimal crest + lacrimal fascia
  - **Insertion** → Passes laterally & forwards → divides into 2 slips → surround the canaliculus → becomes continuous with pretarsal fibers & Riolan's muscle

Actions: (The underlined are the main actions, others are subsidery actions)

(1) Orbital part →
- Main action → *Voluntary forcible closure of the eyelids* → protective against trauma
- Subsidary actions → Depress the eye brow + elevate the cheek

(2) Palpebral part → *Involuntary blinking*
- Spontaneous (Rhythmic)
- Reflex blinking in response to any danger or loud voice

(3) Pars lacrimalis → Helps drainage of tears
- **Closure** of the eyelid → muscle contraction → **-ve pressure** on the lacrimal sac → suction of tears → *Helps tear drainage.*
- **Opening** of the eyelid → muscle relaxation → **+ve pressure** on the lacrimal sac + closure of the punctum → *Force the tears to NLD.*

(4) Pars ciliaris → makes lid margin tight with the eye ball → Prevents epiphora.

Nerve supply: ***Facial nerve*** (IIV) ⇒ Enters the ms from the lateral side
- Upper part → **Temporal & Upper zygomatic** branches
- Lower part → **Lower zygomatic** branch

Applied Anatomy: ⇒ Paralysis (Facial palsy) ⇒ Ectropion

C.T of the eyelids

1- ***Subcutaneous areolar C.T*** → No fat + Absent near lid margin & in the medial & lateral canthi

2- ***Submuscular areolar C.T***

⇒ Communicates above with the subaponeurotic loose areolar C.T layer (dangerous area) of the scalp
→ Pus or blood take its way to Upper lid → Black eye

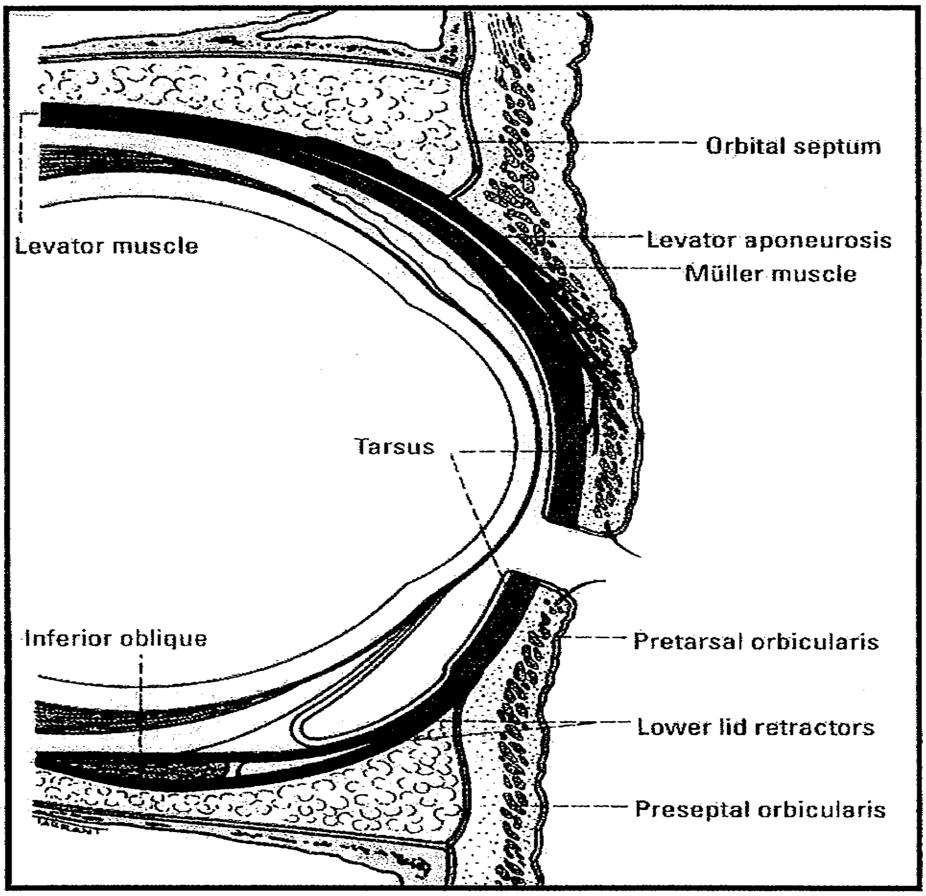
⇒ Sensory nerves of the eyelid present in this layer → Anesthesia should be given in that layer.

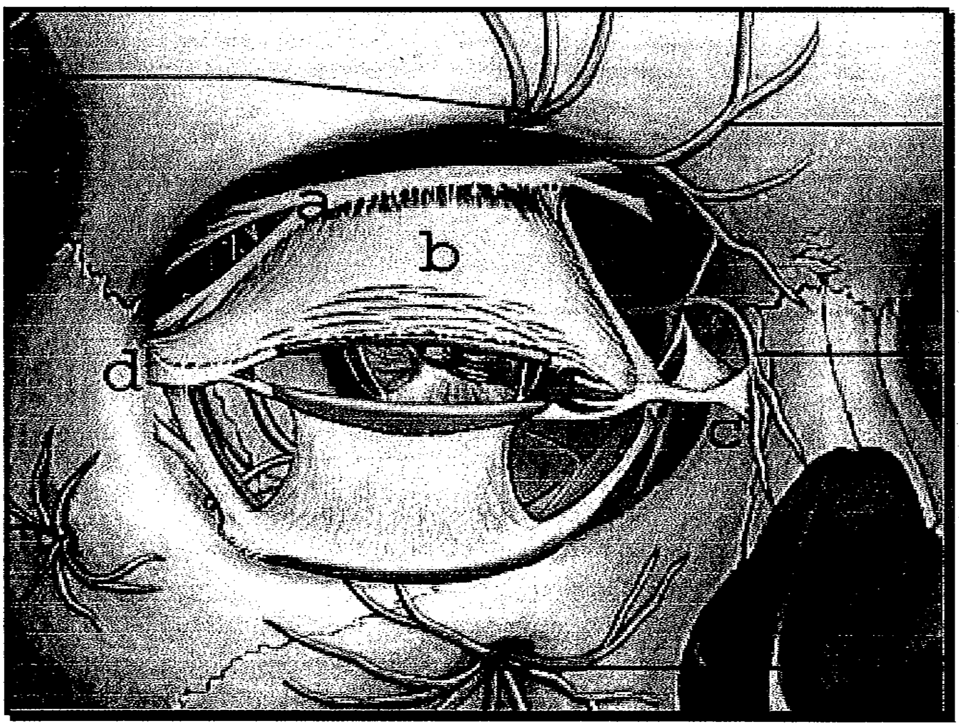
⇒ Reached through the grey line.

⇒ In the upper lid it is divided by the levator fibers into :

(1) Pretarsal space [between tarsus & muller ms (posterior), levator tendon (anterior)]
→ Contains the ***Peripheral arterial archades***

(2) Preseptal space [between orbital septum & levator tendon (posterior) **&** orbicularis ms (anterior)]
→ Bounded above by ***Preseptal cussion of fat*** (betwen orbital septum & orbicularis ms)
It is adherent to Orbicularis & epicranial aponeurosis of the scalp
→ separates subaponeurotic area from preseptal space


Orbital septum
Levator muscle
Levator aponeurosis
Müller muscle
Tarsus
Inferior oblique
Pretarsal orbicularis
Lower lid retractors
Preseptal orbicularis


a
b
c
d

Levator Palpebrae Superioris muscle

- **Origin:**

Back of the roof
(periosteal covering of the lesser wing of sphenoid)
just in front of the optic canal.
(Its origin blends with that of the superior rectus muscle below and the superior oblique muscle medially)

- **Course & insertion:** It runs forward beneath the roof of the orbit to a point about 1 cm behind the orbital septum, where it expands into an ***aponeurosis***, which passes through the orbital septum → inserted in :
  1. The **skin** of the eyelid → form the superior palpebral furrow.
  2. The anterior surface of the **upper tarsus**..
  3. The **medial and lateral palpebral ligaments**
  4. **Sup. fornix**
  5. ***Muller's m.*** (superior tarsal muscle) ⇒ arise from its under surface → inserted in upper border of tarsus
- **Nerve supply:** **Sup. division of oculomotor n.**

(*passes through* the underlying SR to reach the inferior surface of the levator muscle or *turn around* the medial border of SR)
Sympathetic (From carotid plexus → join oculomotor n.)

- **Action:** Elevates upper lid & sup. Fornix Deepens upper palpebral crease
- **Relations:**

Above	Below	In front of the aponeurosis	Behind the aponeurosis
1) Frontal n. 2) Trochlear n. 3) Supraorbital vessels.	1) Sup. Rectus (its medial part) 2) Optic nerve 3) Globe	1) Retroseptal fat 2) orbital septum 3) orbicularis oculi	1) peripheral arterial arcade 2) Palpebral portion of lacrimal gland.

Capsulo-palpebral ligament

In the lower eyelid is equivalent to the aponeurosis of the levator palpebrae superioris muscle in the upper eyelid.

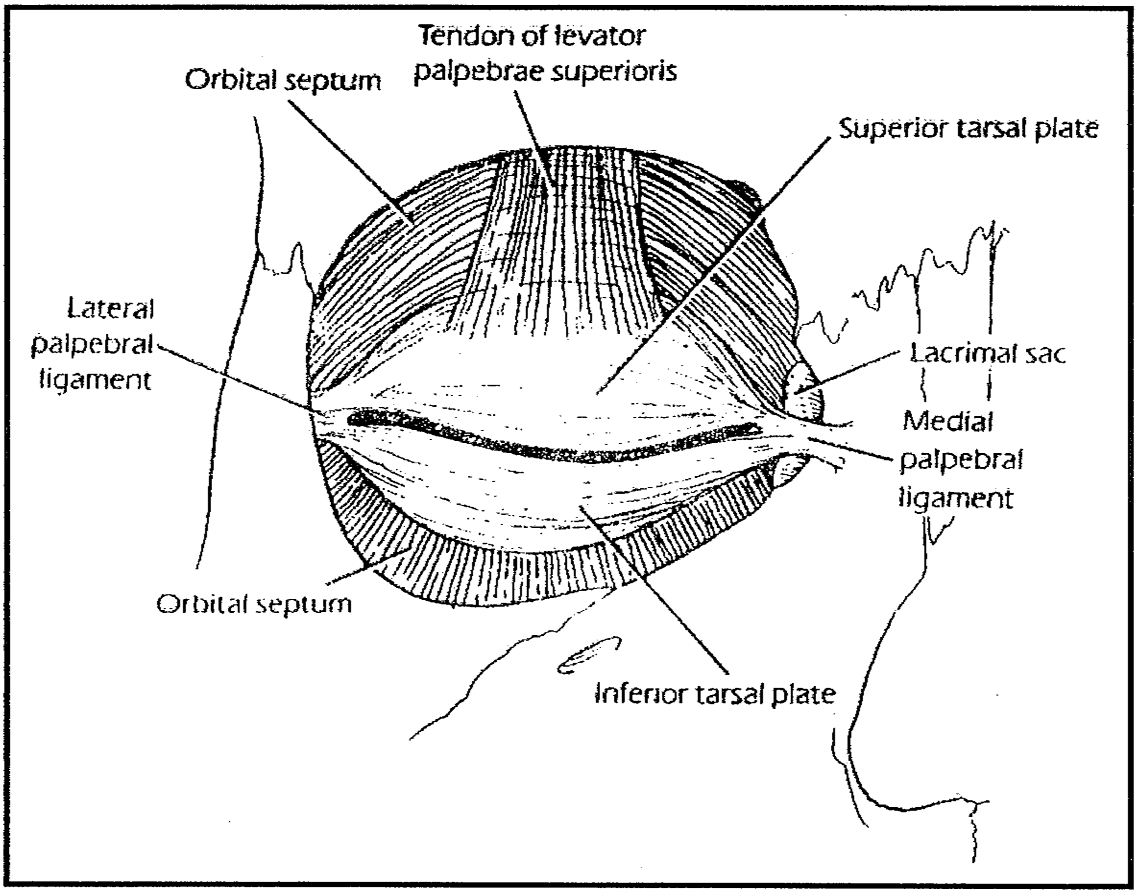
- It extends between
  - ⇒ The fascia of inferior oblique and inferior rectus muscles,
  - ⇒ Tenon capsule,
  - ⇒ The inferior transverse ligament (Lockwood),
  - ⇒ The inferior border of the lower tarsus.
- Its connection with the tarsus makes it the ***principal retractor of the lower eyelid***.

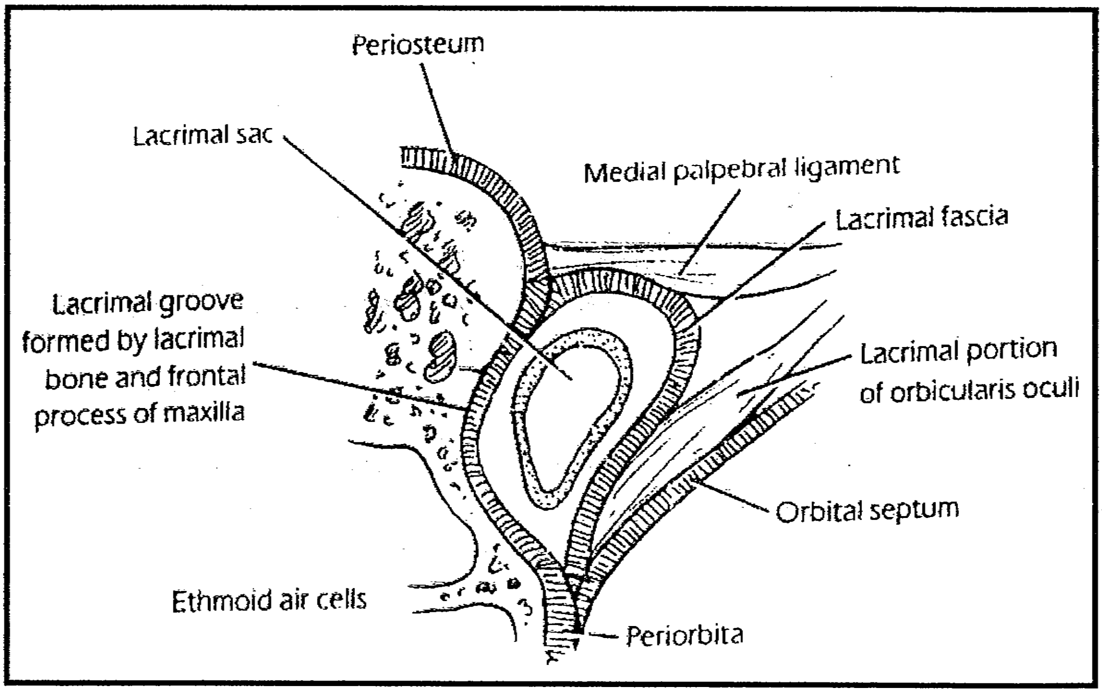
Muller muscle

(Superior & Inferior palpebral smooth muscles) (sympathetic)
→ small sheets of smooth muscle located immediately beneath the **orbital** portion of the palpebral conjunctiva. (The sympathetic supply is distributed with branches of the *ophthalmic a*. to the eyelid)

- The **superior Tarsal muscle**
  - o **Origin**: Undersurface of the ***levator palpebrae superioris*** muscle
  - o **Insertion**: Upper border of upper ***tarsus***
- The **inferior tarsal muscle**
  - o **Origin**: from the ***inferior rectus muscle sheath***
  - o **Insertion**: Lower border of lower ***tarsus*** (and into the facial expansion of IR that inserts into the ***tarsus***)

N.B. Lid retractors = Capsulo-palpebral ligament + Inferior tarsal muscle


Tendon of levator palpebrae superioris
Orbital septum
Superior tarsal plate
Lateral palpebral ligament
Lacrimal sac
Medial palpebral ligament
Orbital septum
Inferior tarsal plate

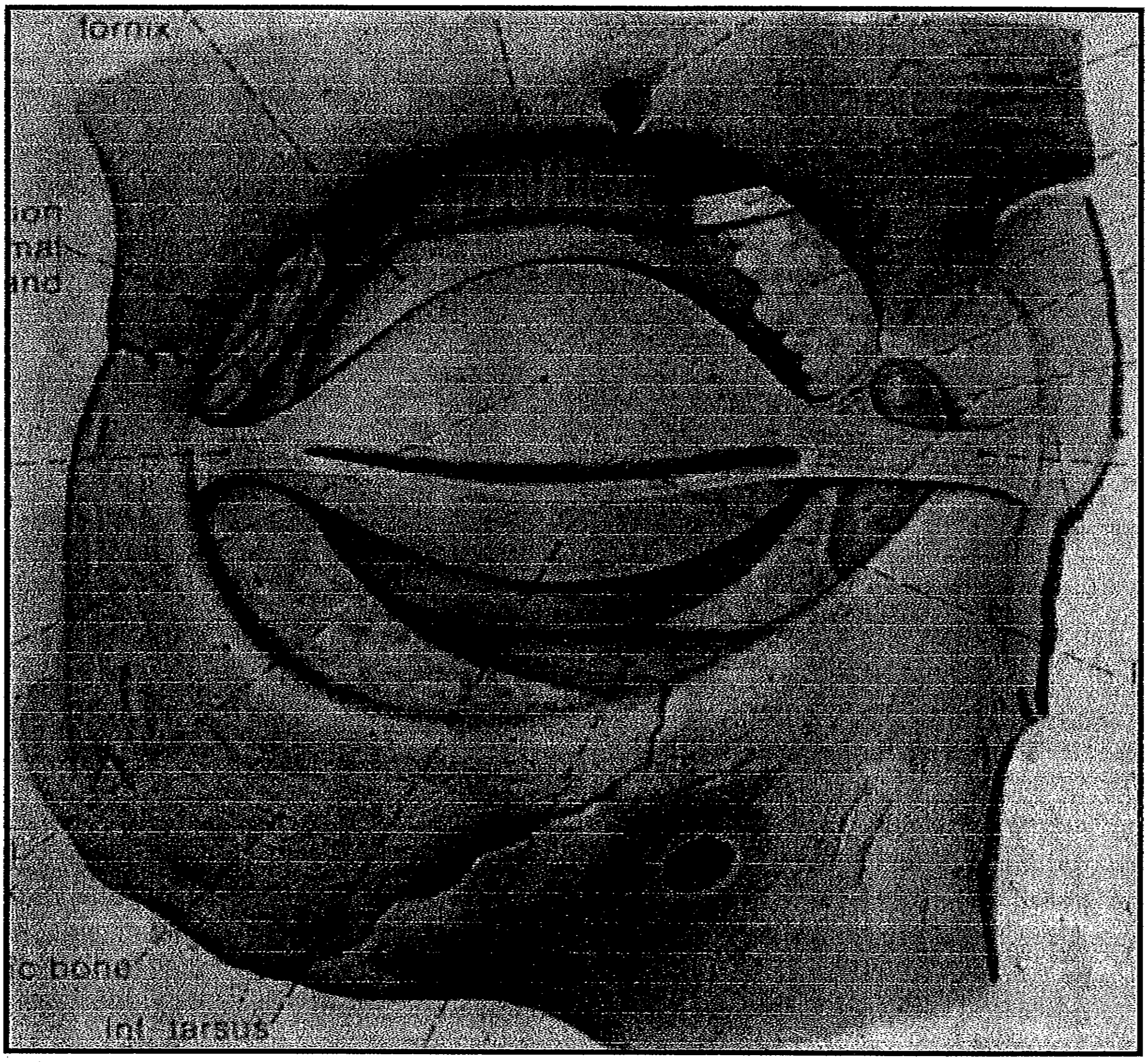

Periosteum
Lacrimal sac
Medial palpebral ligament
Lacrimal fascia
Lacrimal groove formed by lacrimal bone and frontal process of maxilla
Lacrimal portion of orbicularis oculi
Orbital septum
Ethmoid air cells
Periorbita

Orbital Septum

- **Definition:** Flabby portion of the fibrous layer of the lid
- **Structure:** **Fibrous tissue sheet** (2 layers with fibers cross each other at right angles)
- **Function:**
  1) Anatomical barrier between Orbit & eyelid → prevents orbital fat from entering the eyelids & limits the spread of inflammation from the eye lid into the orbit.
  2) Takes part in all movements of the lid.
- **Thickness:**
  - Upper lid > Lower lid
  - Lateral > Medial
- **Attachement:**
  - Centrally
    - ⇒ In upper lid it fuses with the levator aponeurosis slightly above the upper border of tarsus
    - ⇒ In lower lid it attaches to the lower border of the tarsus.
  - Peripherally → upper & lower orbital margins
  - Laterally → it attaches to the ***lateral canthal ligament*** and to the ***Whitnall's tubercle***.
  - Medially → it attaches to the ***posterior lacrimal crest***.

Whitnall's tubercle → cross fronto-zygomatic suture → posterior lip of *superior orbital margin* (bridging the supraorbital notch) → bone behind upper part of *posterior lacrimal crest* → descends on *lacrimal bone* (anterior to medial check lig. & posterior to Lacrimal fascia & MPL) → Crosses the middle of the lacrimal sac → *lacrimal tubercle* (lower part of ant. lacrimal crest) → *lower orbital margin* → *zygomatic arch* → leaves the margin forming premarginal recess of Eisler (fibrous pocket extending few mm on facial aspect of zygomatic bone containing fat) → reach *orbital margin* again just below whitnall's tubercle.

- **Relations:**
  - Anteriorly → Orbicularis oculi muscle
  - Posteriorly → Orbital fat
    - ⇒ In the Upper lid → Fat separate it from (1) lacrimal gland (2) levator ms.
    - ⇒ In the Lower lid → Fat tends to escape through orifices with expansions of IR & IO
- **Structures piercing it:**
  1) ***Lacrimal, Supraorbital, Supratrochlear*** nerve & vessels
  2) ***Infratrochlear n., Dorsal nasal a.,*** *Anastomosis between* ***superior ophthalmic v. & angular v.***
  3) Superior & inferior ***palpebral arteries***
  4) ***LPS*** in upper lid & ***Prolongation of IR*** in lower lid
- **Applied:**
  1. ***Inflammation*** is classified according to the septum → Preseptal cellulitis & orbital cellulitis.
  2. ***Dermatochalisis*** (herniation of periorbital fat) : Along week portions of the septum, especially in elderly ⇒ cosmetic troubles

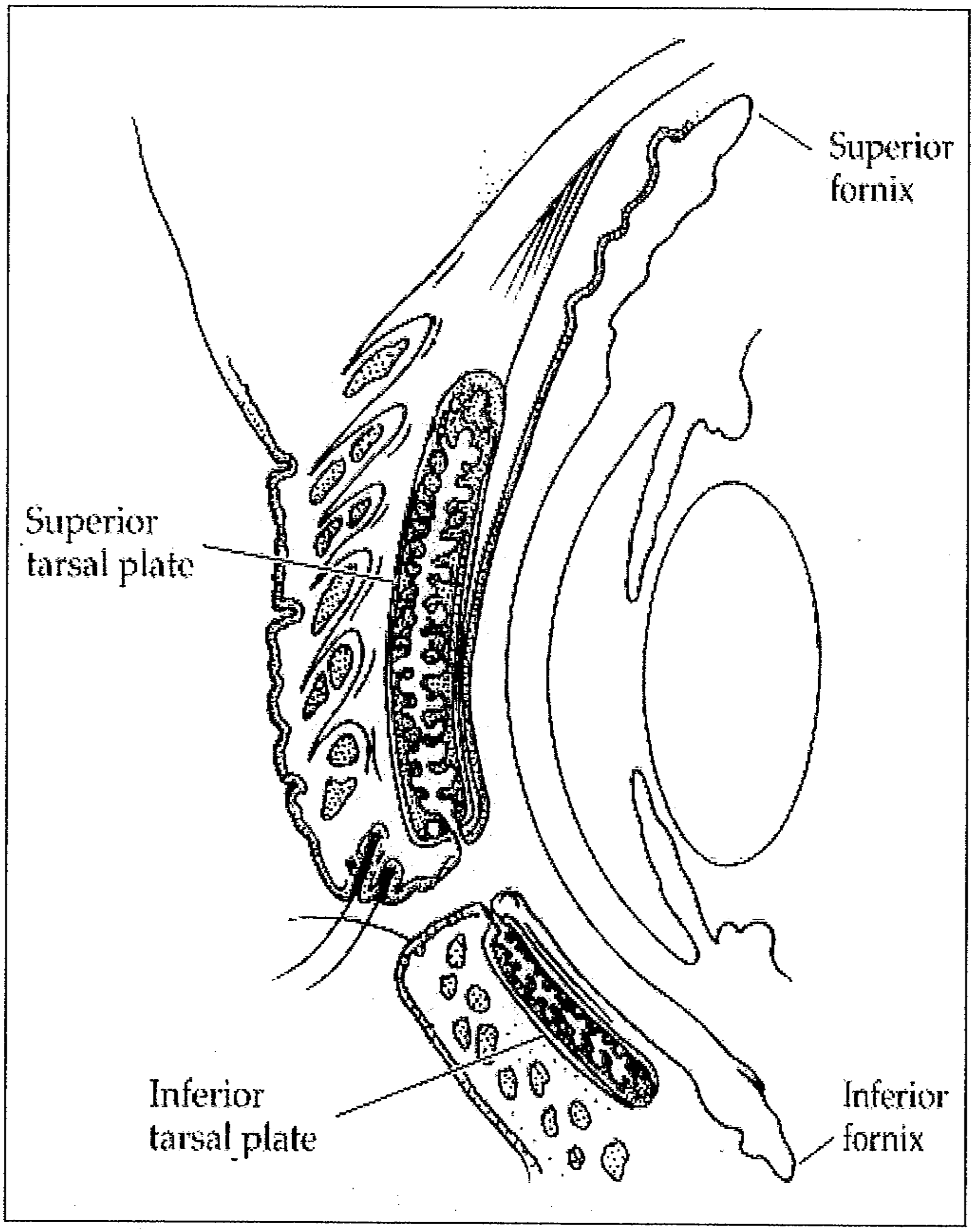

fornix
ion
mal
and
c bone
Inf. tarsus

Medial palpebral ligament

- Definition: **Triangular band** attaching tarsus to medial orbital margin
- Size: **9 mm** in length
- Attachment & parts:
  - Medially → **Frontal process of maxilla** (between ant lacrimal crest & nasomaxillary suture)
  - Laterally → Divided at the anterior lacrimal crest into 2 parts
    - ⇒ Posterior portion ⇒ continuous with **lacrimal fascia** ⇨ **Posterior lacrimal crest**
    - ⇒ Anterior portion ⇒ continues as 2 bands (forming Y shaped band with main ligament) → attaches to **tarsi**
- Relations:
  - Upper border (Indefinite) ⇒ Continuous with ***periosteum*** & ***Lacrimal fascia*** covering the fundus
  - Lower border (Definite) ⇒ Fibers of ***orbicularis oculi*** insinuate themselves under it.
  - Anterior surface (Adherent to skin) ⇒ **Angular vessels.**
  - Posterior surface ⇒ ***Lacrimal sac & fascia*** + ***Orbital septum***
- Applied:
  - **Superolateral traction of lateral canthus** ⇒ MPL prominent (on frontal process of maxilla)
  - **Lacrimal sac swelling** ⇒ usually presents below the MPL (except if fundic)
  - **Better exposure of lacrimal sac during DCR** may need cut of MPL

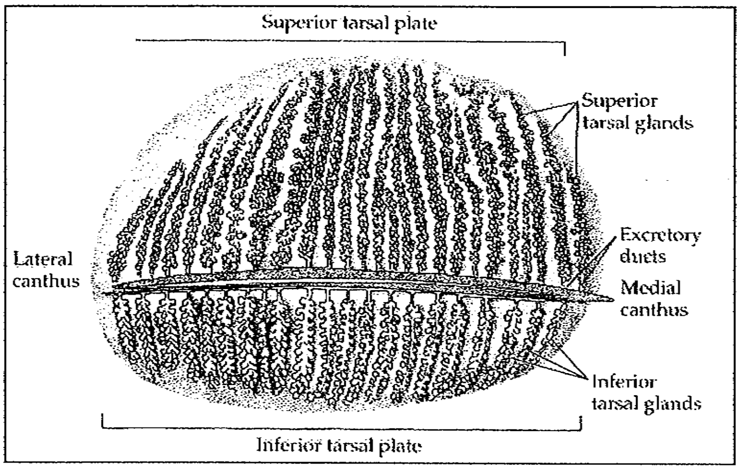
Lateral palpebral ligament

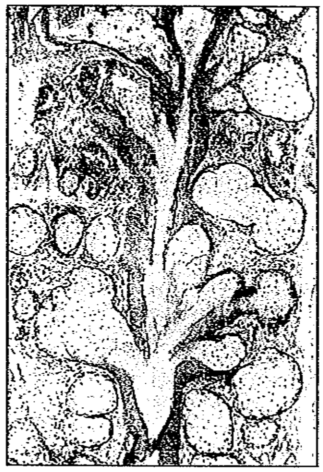
- Definition: Areolar tissue of orbital septum behind lateral palpebral raphae
- Size: **7 X 2 mm**
- Attachment:
  - Medially → **Tarsus**
  - Laterally → **Whitnall's tubercle** (11 mm below Fronto-zygoatic suture)
- Relations:
  - Upper border ⇒ united with expansion of LPS.
  - Lower border ⇒ united with expansion of IO & IR
  - Anterior surface ⇒ **Riolan** ms + Few **lacrimal gland** lobules + Lateral palpebral **raphae** + **orbital septum**
  - Posterior surface ⇒ Few **lacrimal gland** lobules + **Lateral check ligament**

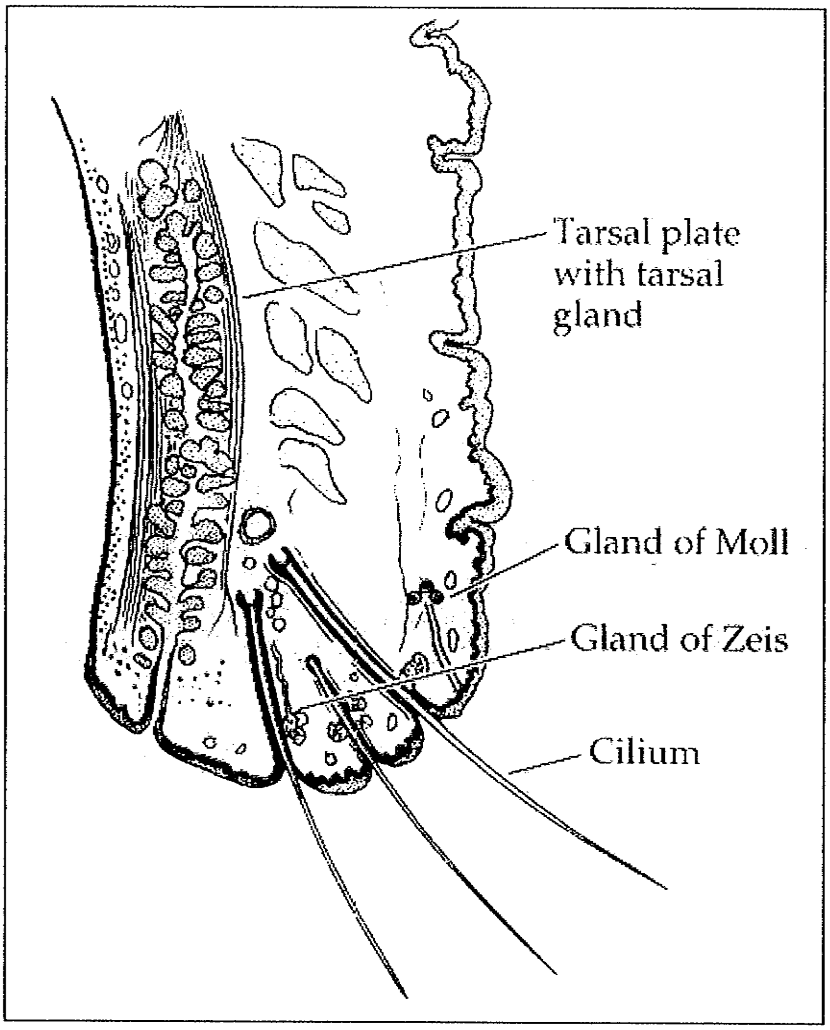

Superior
fornix
Superior
tarsal plate
Inferior
tarsal plate
Inferior
fornix

The tarsal plates

- Structure: Dense fibrous C.T (not cartilage)
- Function: → ***Structural framework*** of the eyelid → gives form and density to the free margin of the eyelids.
- Measures:
  - Thickness : **1** mm
  - Length: **25 - 30** mm
  - Height: upper tarsus measures about **11** mm , and the lower tarsus about **5** mm.
- Extent: From the ***lacrimal puncta*** medially to the ***lateral canthus***.
- Attachement & Relations:
  - **The posterior surface**
    1) Concave
    2) Firmly attached to the tarsal conjunctiva
  - **The anterior surface**
    1) Convex
    2) Separated from the orbicularis oculi muscle by loose areolar tissue.
    3) Levator ms is inserted into it.
  - **The free margin** → Thick & forms lid margin
  - **The attached margin** → Thin & gradually merges into the orbital septum & attaches to Muller ms.
  - **Medially and laterally** → the tarsal plates attach to palpebral ligaments.
- Meibomian Glands:


Superior tarsal plate
Superior tarsal glands
Excretory ducts
Lateral canthus
Medial canthus
Inferior tarsal glands
Inferior tarsal plate




Tarsal plate with tarsal gland
Gland of Moll
Gland of Zeis
Cilium

Glands of the lids

A. Meibomian glands

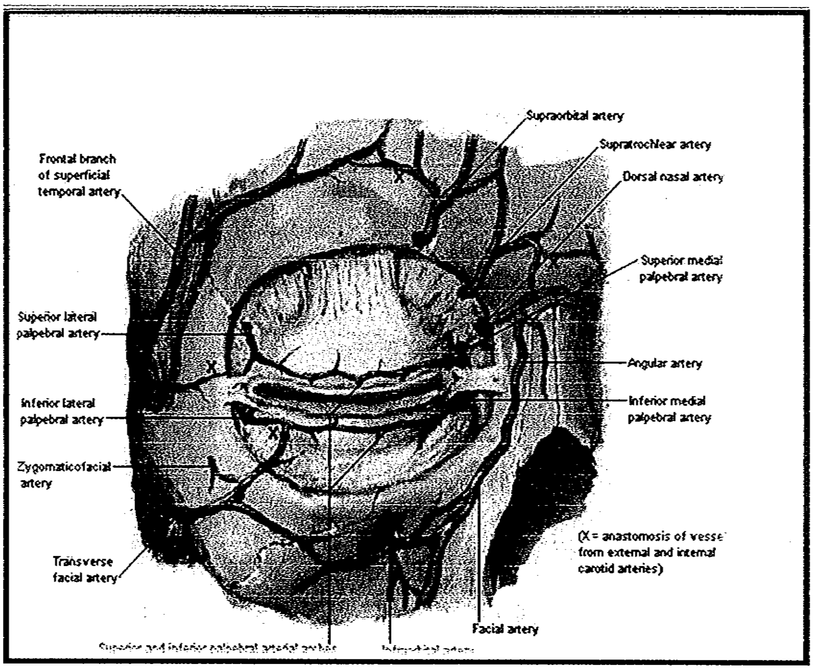
- Definition: **Modified sebaceous glands** that are not related to hair follicles.
- Embryology: Inward growth of the **surface ectoderm** behind the cilia, that canalize to form secretory and ducts of the glands.
- Site:
  - **Arranged as**
    1) single row
    2) Embeded in the substance of tarsus
    3) Run from the attached to the free border
  - **The orifices** of the canals form the ***white line*** on the lid margin just behind the ***grey line***.
- Number: Upper eyelid → **25** Lower eyelid → **20**
- Gross: They appear on everting the eye lid as ***long yellow subconjunctival structures***.
- Structure:
  - Each consists of ***10-15 globular acini*** placed around a ***central canal*** opens onto the lid margin
    - ⇒ **Canal** ⇒
      - → lined by 4 layers of cells rested on basement membrane
      - → As we approach the mouth **(1)** Cells become arranged in **6 layers** **(2) Keratinization** ↑
    - ⇒ **Acini** ⇒ lined by polyhedral cells
- Function: secretes **sebaceous** (oily) **secretion**
  (1) Prevents the ***overflow*** of tears,
  (2) Provides the external layer of the precorneal tear film → prevents ***rapid evaporation*** of tears.
  (3) Ensures an ***airtight closure*** of the eyelids
  (4) Prevents ***sticking*** of the eyelids

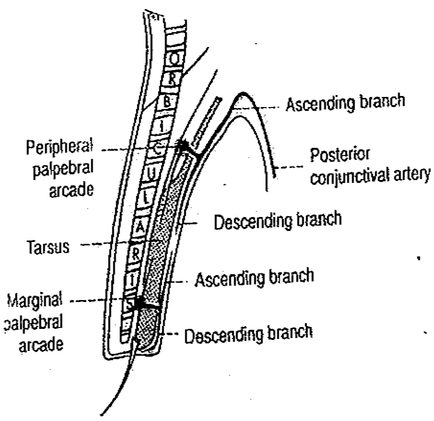
B. Glands of Moll

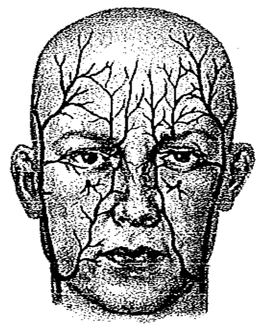
- Definition: **Modified sweat gland** which have been arrested in development.
- Site:
  - **Arranged** obliquely & parallel to the bulbs of cilia
  - **The orifices** open into the **follicles** or **directly onto the eyelid margin** between the cilia.
- Number: **Lower** eyelid > **Upper** eyelid
- Structure: Unbranched spiral tubules formed of:
  - **Secretory portion** ⇒ lined by
    (1) Cylindrical cells (containing secretory & fatty granules) resting on a BM.
    (2) Myoepithelial cells (between cells & basement membrane).
  - **Ducts** ⇒ lined by 1-2 layers of cells, the superficial one is cylinder.

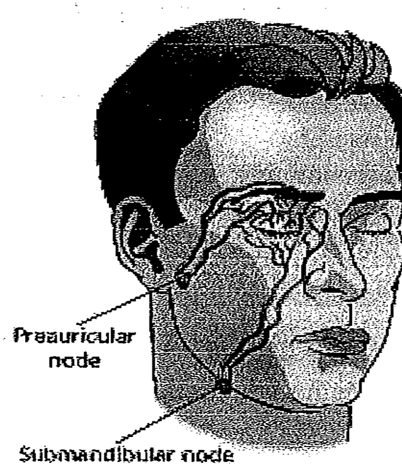
C. Glands of Zeis

- Definition: **Modified sebaceous glands**
- Site: Attached directly & open into the **follicle of cilium**
- Number: **2** for each cilium
- Structure: Cubical cells (multiplying to form polyhydral cells) resting on a BM.
- Function: secretes **Sebaceous** (oily) **secretion** → Prevents lashes from dryness.






Black: from internal carotid artery (via ophthalmic artery)
Red: from external carotid artery



Blood supply:

Arterial:

- **ICA**
  - *Ophthalmic a.* (mainly)
    1) Lacrimal a. ⇒ *Lateral palpebral arteries*
    2) *Medial palpebral arteries*
    3) Supraorbital a.
    4) Dorsal nasal a.

  (Lateral & Medial palpebral arteries ⇒ Marginal & Peripheral **vascular arcades**)
- **ECA**
  - *Superficial temporal* ⇨ Transverse facial + Zygomatico orbital
  - *Maxillary* ⇨ Infraorbital

Marginal arterial archades = Tarsal archades
- Found → In the submuscular areolar CT (between Tarsus & orbicularis oculi) at the lid margin
- Formed by → Anastomosis between ***medial & lateral palpebral as.*** (after piercing the orbital septum)
- Receives → Anastomosing twigs from Branches of ECA

Peripheral arterial archade = Arcus tarsus superior (in the upper eyelid only)
- Found → In front of the upper margin of the tarsus.
- Formed by → ***Superior branch of the Medial palpebral a.***

From the 2 archades ⇒ Branches
⇒ Pass **forward** → Supply orbicularis oculi & skin
⇒ Pass **backward** → Supply tarsus. & conjunctiva

Venous:

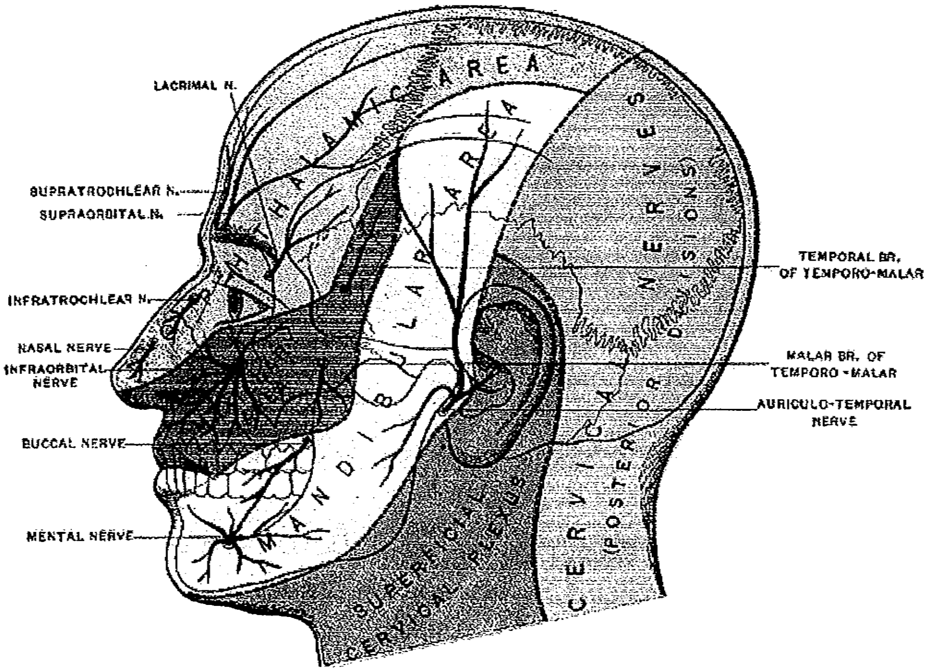
- They follow arteries but more numerous and arranged into:
  - **Pre-tarsal** plexus (drains skin & muscle)→ Drained by *Facial* vein
  - **Post-tarsal** plexus (drains conjunctiva & tarsus)→ Drained by *ophthalmic* vein

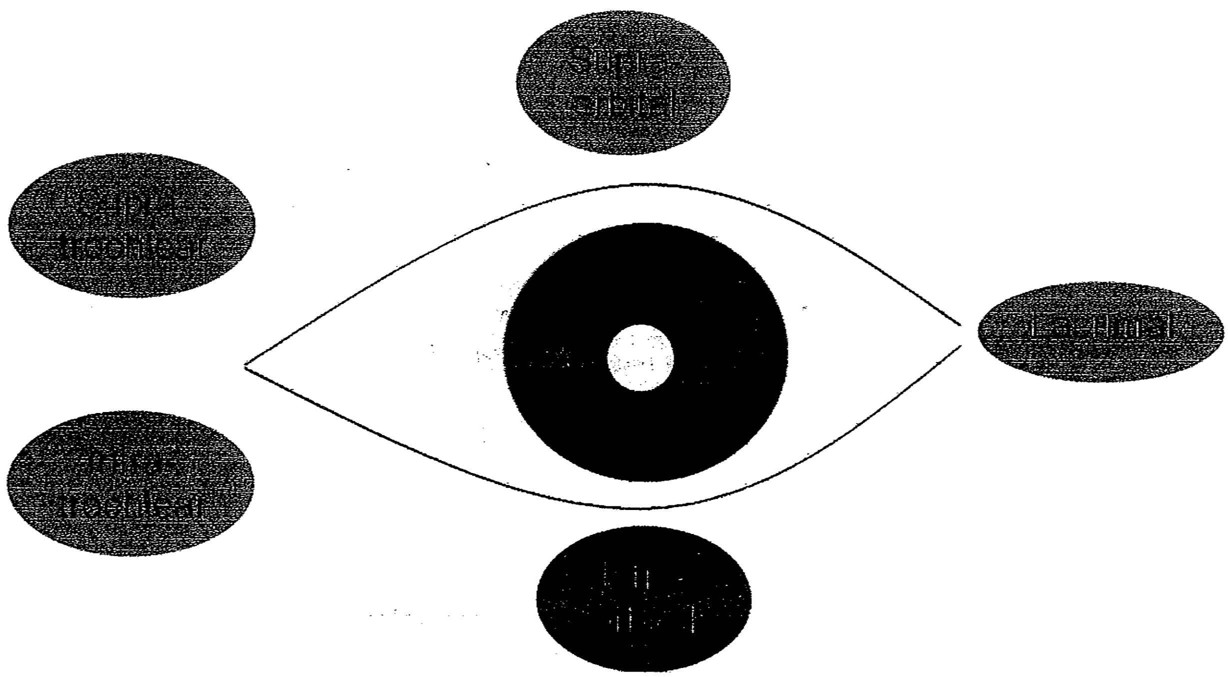
N.B some of the veins are drained into veins of the forehead & temple

Lymphatic supply :

- Arranged into:
  - **Pre-tarsal** plexus (drains skin & muscle)
  - **Post-tarsal** plexus (drains conjunctiva & tarsus)
- Drained by two groups of lymphatic vessels:
  - **Medial** group: drains the medial 2/3 of the lower eyelid and the medial 1/3 of the upper eyelid into the ⇒ *submandibular* lymph nodes.
  - **Lateral** group: drains the lateral 1/3 of the lower eyelid and lateral 2/3 of the upper eyelid into the ⇒ *preauricular* & *Superficial parotid* lymph nodes.

  Both of them ⇒ *Upper deep cervical* lymph nodes.


LACRIMAL N.
SUPRATROCHLEAR N.
SUPRAORBITAL N.
INFRATROCHLEAR N.
NASAL NERVE
INFRAORBITAL NERVE
BUCCAL NERVE
MENTAL NERVE
TEMPORAL BR. OF TEMPORO-MALAR
MALAR BR. OF TEMPORO-MALAR
AURICULO-TEMPORAL NERVE
SUPERFICIAL CERVICAL PLEXUS
CERVICAL NERVES
(POSTERIOR DIVISIONS)


Supra-orbital
Supra-trochlear
Lacrimal
Infra-trochlear

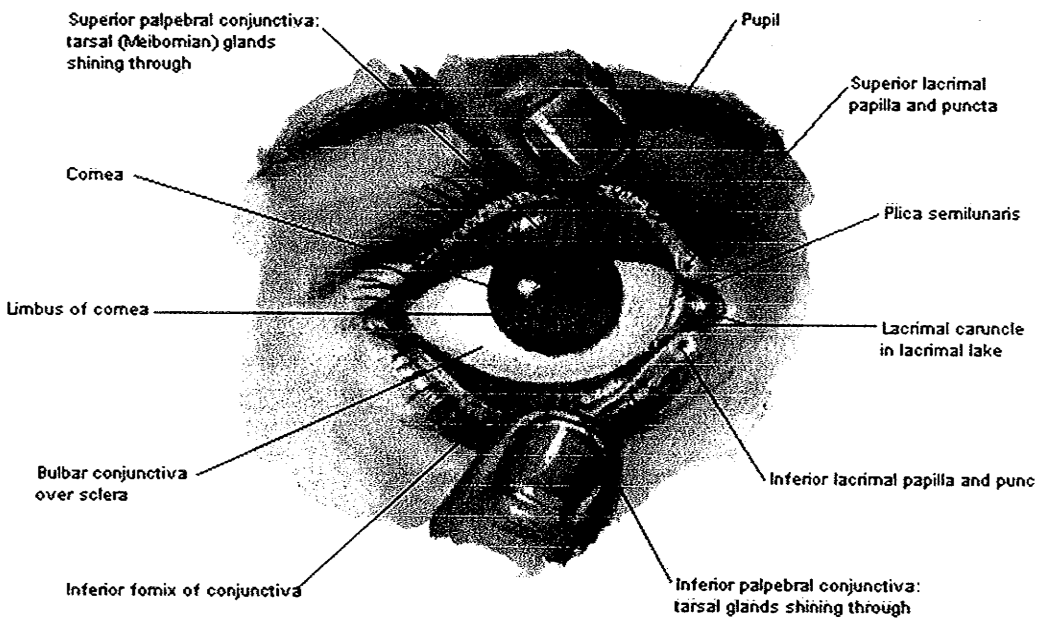
□ Nerve supply:

- **Sensory** (Trigeminal nerve)
  - The ophthalmic ⇒ the **upper** eyelid and to a small lateral portion of the lower eyelid.
  - The maxillary ⇒ the remaining medial portion of the **lower** eyelid (through branches of the infraorbital nerve)

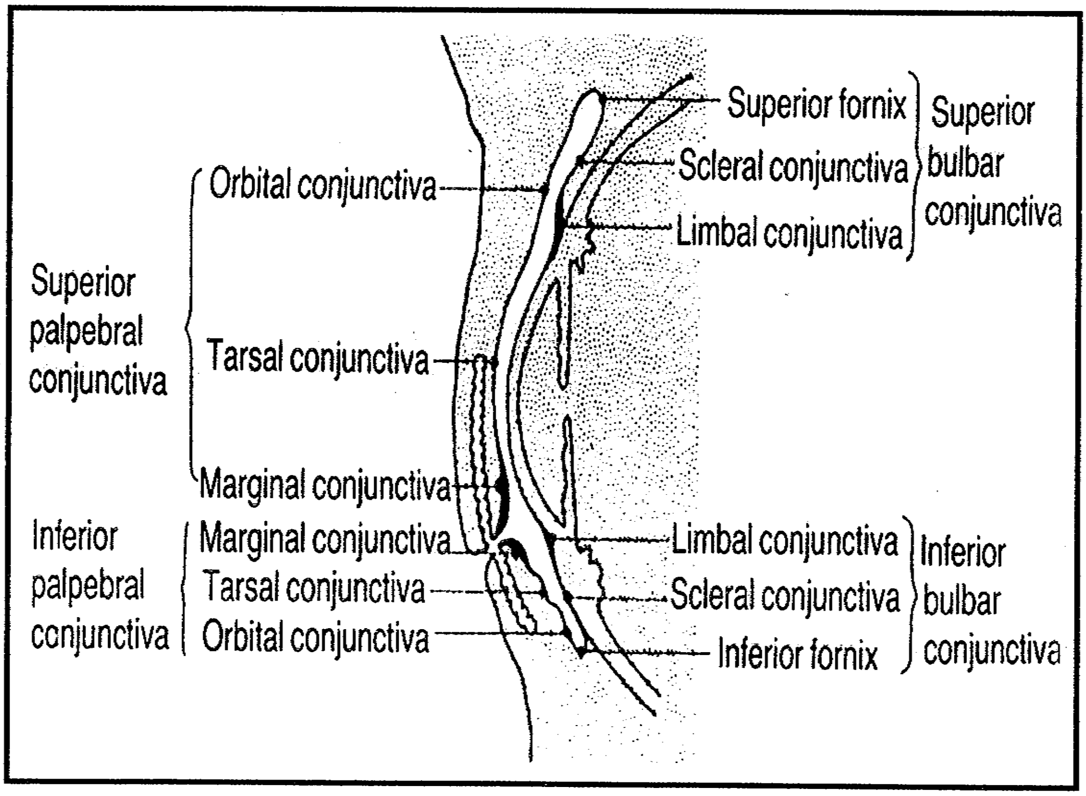
Upper eyelid	Lower eyelid
• Medially → supra & infratrochlear ns.	• Medially → Infratrochlear n.
• Center → ***Supraorbital n.***	• Center → ***Infraorbital n.*** (From maxillary)
• Laterally → lacrimal n.	• Laterally → Lacrimal n.

- **Motor**
  - **Facial nerve** (N VII) ⇒ orbicularis oculi muscle.
  - **Oculomotor nerve** (N III) ⇒ levator palpebrae superioris muscle.

- **Sympathetic** Postganglionic sympathetic fibers from the superior cervical ganglion innervate the ***Muller's muscle***. They enter the orbit with the superior division of occulomotor → Nerve to LPS → Muller muscle.



Superior palpebral conjunctiva: tarsal (Meibomian) glands shining through
Pupil
Superior lacrimal papilla and puncta
Cornea
Plica semilunaris
Limbus of cornea
Lacrimal caruncle in lacrimal lake
Bulbar conjunctiva over sclera
Inferior lacrimal papilla and punc
Inferior fornix of conjunctiva
Inferior palpebral conjunctiva: tarsal glands shining through



Superior fornix
Scleral conjunctiva
Limbal conjunctiva
Superior bulbar conjunctiva
Orbital conjunctiva
Superior palpebral conjunctiva
Tarsal conjunctiva
Marginal conjunctiva
Inferior palpebral conjunctiva
Marginal conjunctiva
Tarsal conjunctiva
Orbital conjunctiva
Limbal conjunctiva
Scleral conjunctiva
Inferior fornix
Inferior bulbar conjunctiva

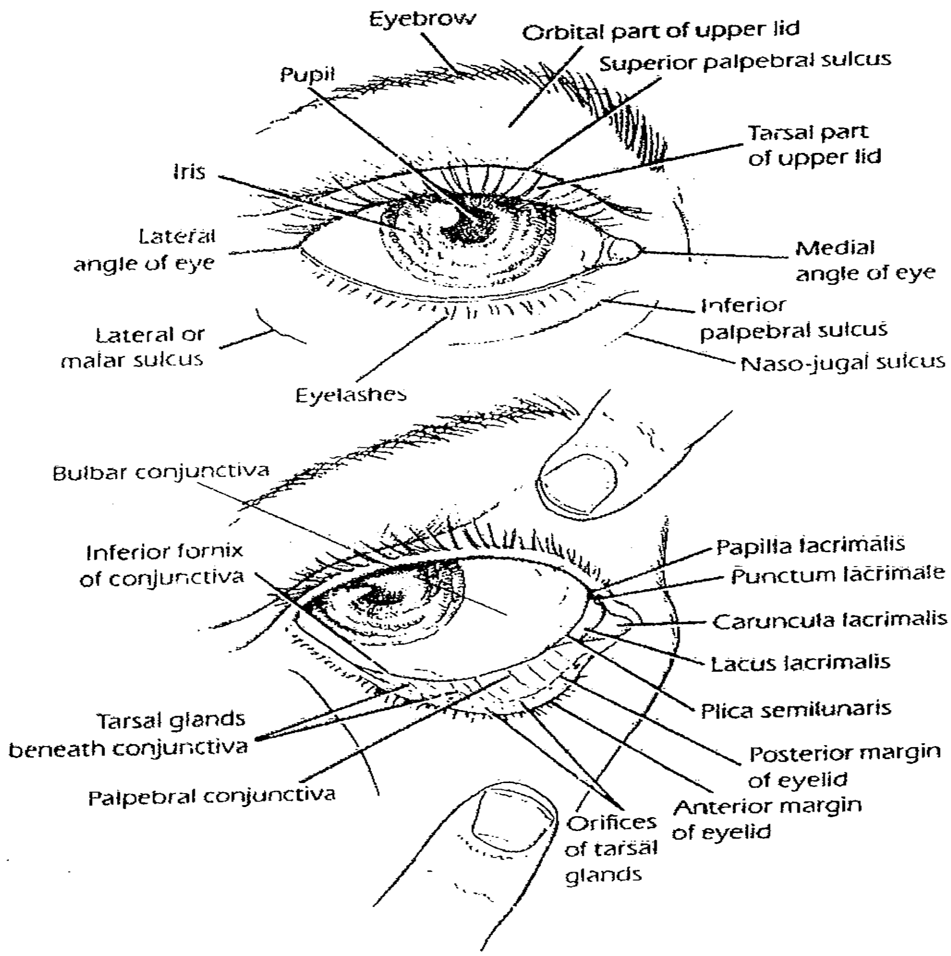
Conjunctiva

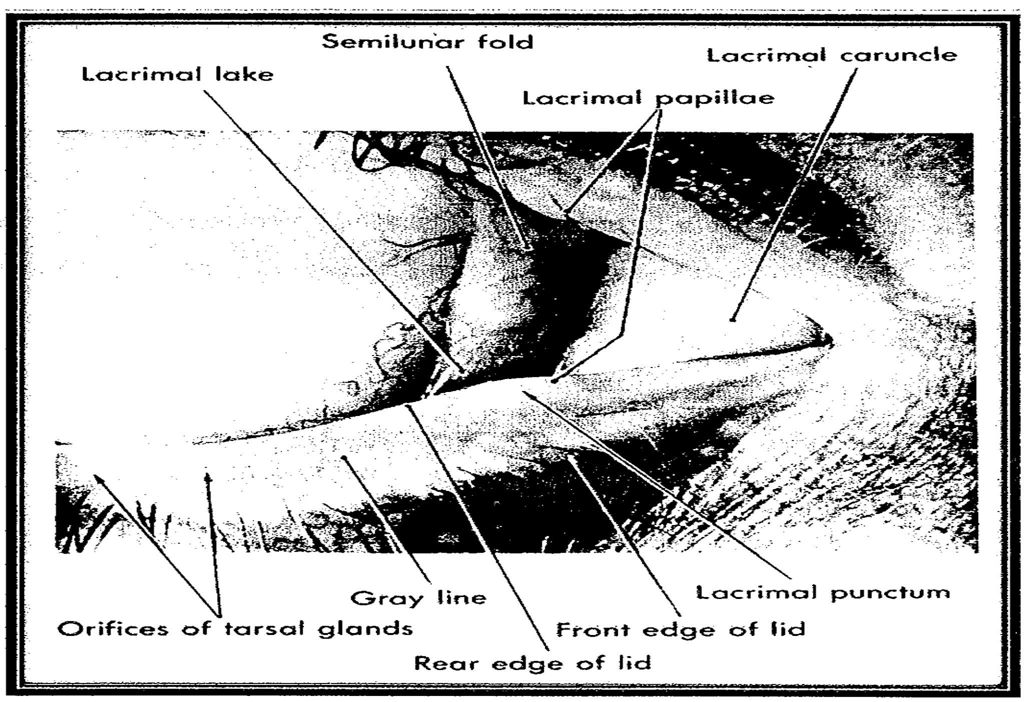
□ **Definition:**

- A thin, transparent mucous membrane that lines the inner surface of the eyelids and covers the anterior portion of the sclera.
- Its epithelium is continuous with that of the cornea and with the lacrimal drainage system through the puncta.

□ **Parts** (Gross): The conjunctiva is divided into three areas:

- The **palpebral conjunctiva** is divided into:
  - *Marginal* portion
    - → From the ***white line*** till ***sulcus subtarsalis*** (shallow groove 2mm above the lid margin)
    - → Transitional zone between the skin & conjunctiva.
    - → Lacrimal puncti open at it.
  - *Tarsal* portion:
    - → From ***sulcus subtarsalis*** to the ***upper border of tarsus***
    - → Thin, Transparent (showing tarsal glands as yellow streaks) & Vascular (examined for anemia)
    - → Firmly adherent to the *whole tarsus* (upper lid) & ½ *tarsus* (lower lid)
  - *Orbital* portion:
    - → From ***upper border of tarsus*** to the ***fornix***
    - → Thrown into many folds.
    - → Loosely adherent to the underlying *Muller's muscle*
- The **conjunctiva of the fornices**
  - → A ***continuous circular cul-de-sac*** [broken only on medial side, extends superiorly & inferiorly for → **8 mm** and laterally for → **14 mm** (just post to the equator) from the limbus]
  - → loosely adherent to the underlying tissue & may become markedly swollen
  - → Attached to the fascial expansion of the sheathes of the levator & recti muscles.
- The **bulbar conjunctiua**
  - → From the ***fornix*** to the ***limbus***
  - → Thin & transparent (Showing the sclera as the "**white**" of the eye)
  - → Attachment to the sclera.
    1. In **all parts** except limbus ⇒ The conjunctival stroma is loosely attached to the underlying Tenon capsule → ***Easily dissected***
    2. At 3 mm from **limbus** ⇒ The conjunctival stroma is firmly adherent & fuses into a dense fibrous tissue with the Tenon capsule & the sclera.
       - → ***Difficult to raise conjunctival flap***
       - → ***A firm hold of the globe can be obtained with forceps***


Eyebrow
Orbital part of upper lid
Superior palpebral sulcus
Pupil
Tarsal part
of upper lid
Iris
Lateral
angle of eye
Medial
angle of eye
Inferior
palpebral sulcus
Lateral or
malar sulcus
Naso-jugal sulcus
Eyelashes
Bulbar conjunctiva
Inferior fornix
of conjunctiva
Papilla lacrimalis
Punctum lacrimale
Caruncula lacrimalis
Lacus lacrimalis
Plica semilunaris
Tarsal glands
beneath conjunctiva
Posterior margin
of eyelid
Palpebral conjunctiva
Anterior margin
of eyelid
Orifices
of tarsal
glands


Semilunar fold
Lacrimal caruncle
Lacrimal lake
Lacrimal papillae
Gray line
Lacrimal punctum
Orifices of tarsal glands
Front edge of lid
Rear edge of lid

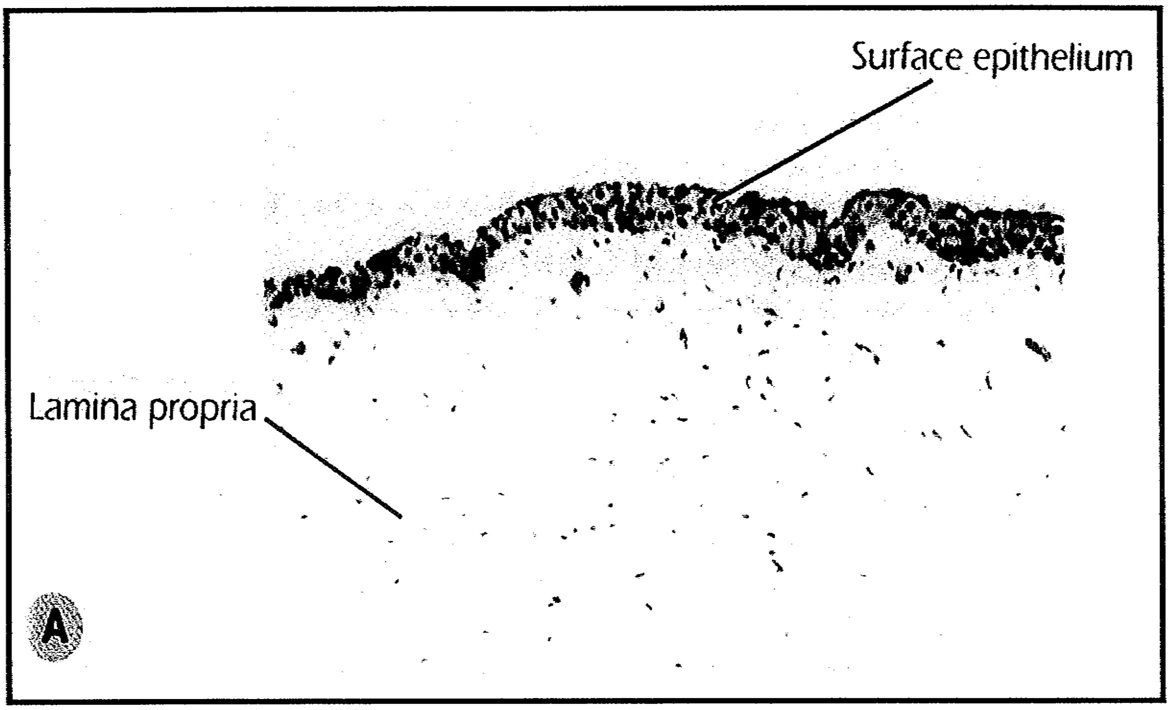
- At the medial angle of each eye
  - The **semilunar fold** (plica semilunaris):
    - → A ***delicate vertical crescent of conjunctiva***, the free edge of which is concave and concentric with the corneal margin.
    - → Separated from the bulbar conjunctiva by the 2mm-deep cul-de-sac.
  - The **lacrimal caruncle**: (= caro = flesh)
    - → **Definition**: It is a minute piece of ***modified skin*** located in the lacus lacrimalis medial to the semilunar fold.
    - → **Structure**:
      1) It is covered by str. Squ. non keratinized epithelium.
      2) It contains large sebaceous glands similar to meibomian glands
      3) It has fine hairs with sebaceous glands similar to the glands of Zeis.
    - → **Blood supply** → Superior medial palpebral artery.
    - → **Lymphatic drainage** → Submandibular lymph nodes.
    - → **Nerve supply** → Infra-trochlear nerve.
    - → More apparent when the eye is rotated laterally. (caused by the lateral attachment to plica)
    - → Deeply recessed when the eye is rotated medially. (caused by the deep attachment of MR sheath)

□ **Structure:** 2 layers:

- **Epithelium:** ***Stratified squamous non keratinized epithelium:***

A. *Varies in Thickness* (according to site)

- Free lid margin → Stratified Squamous Keratinized epithelium
- Muco-cutaneous junction → **5 cell layers** (Str. Squ. non keratinized epith)
  (1) Deep cylindrical
  (2) Superficial flattened
- Tarsal conjunctiva
  - ⇒ Upper tarsal → **2 cell layers**
    (1) Deep cubical cells (oval nuclei parallel to the surface)
    (2) Superficial cylindrical cells (oval nuclei perpendicular to the surface)
  - ⇒ Lower tarsal → **4 cell layers** (from basal to superfical)
    (1) Cubical
    (2) Polygonal
    (3) Wedge shaped
    (4) Cone-shaped cells
- Bulbar conjunctiva → Stratified columnar epithelium
- Limbus → **5-7 cell layers**
  (1) Deep cylindrical (large stained nuclei & minimal cytoplasm & pigment granules)
  (2) Middle plygonal cell layers with no desmosomes (unlike cornea)
  (3) Superficial flat cells (oval nuclei parallel to the surface)


Surface epithelium
Lamina propria
A

B. *Varies in structure* (according to site)

- Type of Epithelium
  1) Near the muco-cutaneous junction (palpebral conjunctiva)→ Stratified Squamous.
  2) Near the limbus (bulbar conjunctiva) → Stratified Columnar.
- Papillary or epidermal structure (vascular core of C.T of lamina propria covered by epithelium) → more at the ***mucocutaneous junction*** (lid margin) & ***limbus*** (stratified like skin but not keratinized)
- Presence of goblet cells → being more numerous in the ***fornices*** & ***Plica semilunaris*** → less in ***bulbar & tarsal*** conjunctiva → absent at the mucocutaneous junction & limbus.

C. Cells

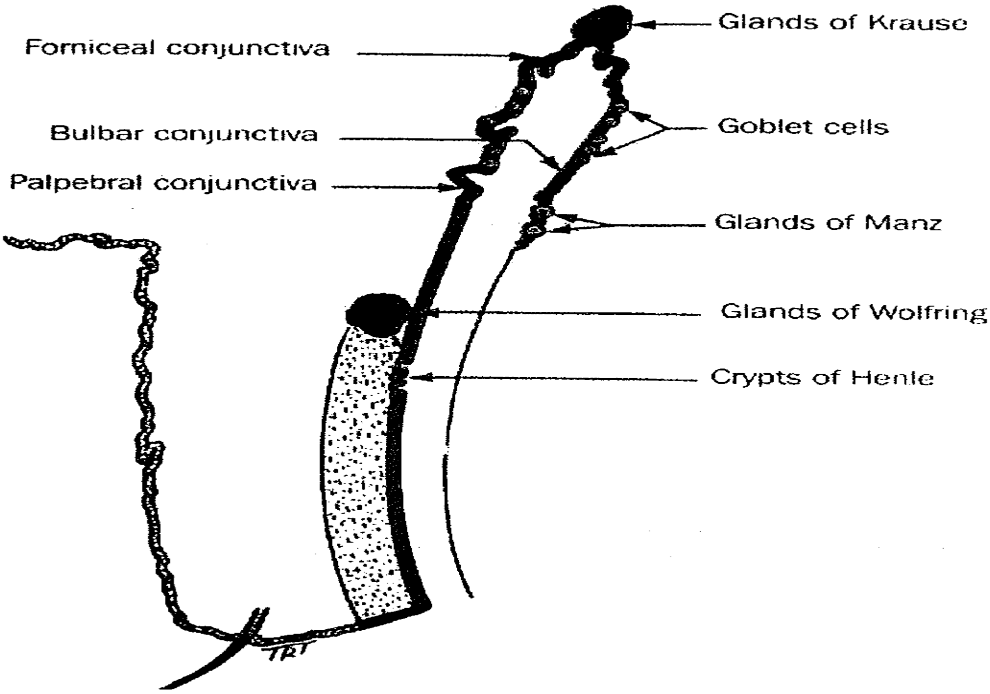
- Epithelial cells
  1. Basal cells → large electron dense nucleus & attached to BM by hemidesmosomes
  2. Intermediate cells
  3. Surface cells → microvilli & numerous vesicles (containing glycocalyx)
- Goblet cells (see later)
- Melanocytes
  1. Present at limbus, fornix, plica, caruncle & the site of perforation of ant. ciliary vs.
  2. Present in **all races** (even white), but only pigmented in coloured races
- Langerhan's cells (Antigen presenting cells) → induce primary immune response
- Intraepithelial lymphocytes → normally present, but ↑ in number in inflammations.

D. *After 3 months of age*, the development of the adenoid tissue makes the conjunctival surface moderately irregular.

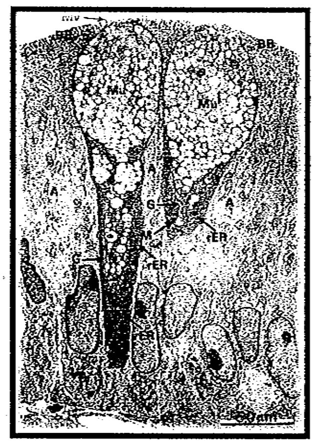
- **Lamina propria:** (adenoid and fibrous layer)

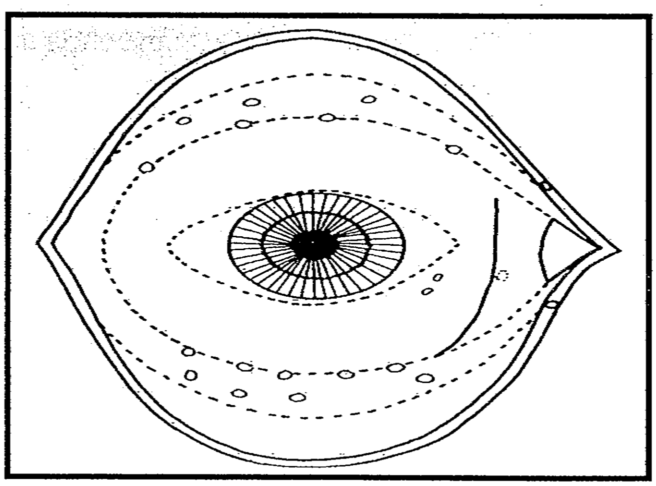
  Connective tissue containing blood vessels, nerves, conjunctival glands, PNL, mast cells, lymphocytes, eosinophils and macrophages. ⇒ Layers :

  1) ***Superficial Adenoid (lymphoid) Layer:***
     - ⇒ **Present in** The bulbar and fornix conjunctiva and the orbital portion of the palpebral
     - ⇒ **Composed of** many lymphocytes enmeshed in a fine reticular network.
     - ⇒ **True lymphatic follicles** (with pale germinal center) are not present except in childhood and in follicular conjunctivitis.
  2) ***Deep Fibrous Layer:*** continuous with the inner margins of the tarsal plates and contains Muller's muscle


Forniceal conjunctiva
Bulbar conjunctiva
Palpebral conjunctiva
Glands of Krause
Goblet cells
Glands of Manz
Glands of Wolfring
Crypts of Henle


Goblet cells





▯ Glands:

- ***Goblet cells*** (numerous unicellular mucous glands) (mention it with epithelium)
  - Site:
    - ⇒ Located in the ***epithelium.***
    - ⇒ Most numerous in the ***fornices*** & ***Plica semilunaris*** → less in the bulbar & tarsal conjunctiva → absent at the muco-cutaneous junction & limbus. (concentrated inferonasally)
  - Shape: Large oval or rounded cells with flat nuclei sitiuated near the base.
  - Origin: Derived from ***basal epithelium*** → migrate towards the surface (remains attached to B.M through a pointed process) → destroyed once they have discharged their contents.
  - Function: Unicellular mucous glands ⇒ Secrete ***mucin***
    1) wetting the corneal & conjunctival epithelium.
    2) Fills any corneal defects.

N.B Removal of these cells → xerosis of the conjunctiva, unlike removal of lacrimal gland → no xerosis.

- ***Accessory lacrimal glands***: ⇒ responsible for basal secretion

1) The glands of ***Krause***
   - Site:
     - ⇒ located deep in the substantia propria,
     - ⇒ Most are located in the fornices of temporal 1/3 of the conjunctiva. (also in the caruncle)
   - Number: Upper fornix → **42** Lower fornix → **6-8**
   - Function: accessory lacrimal glands (They have the histologic structure and secretion of the lacrimal gland proper.)

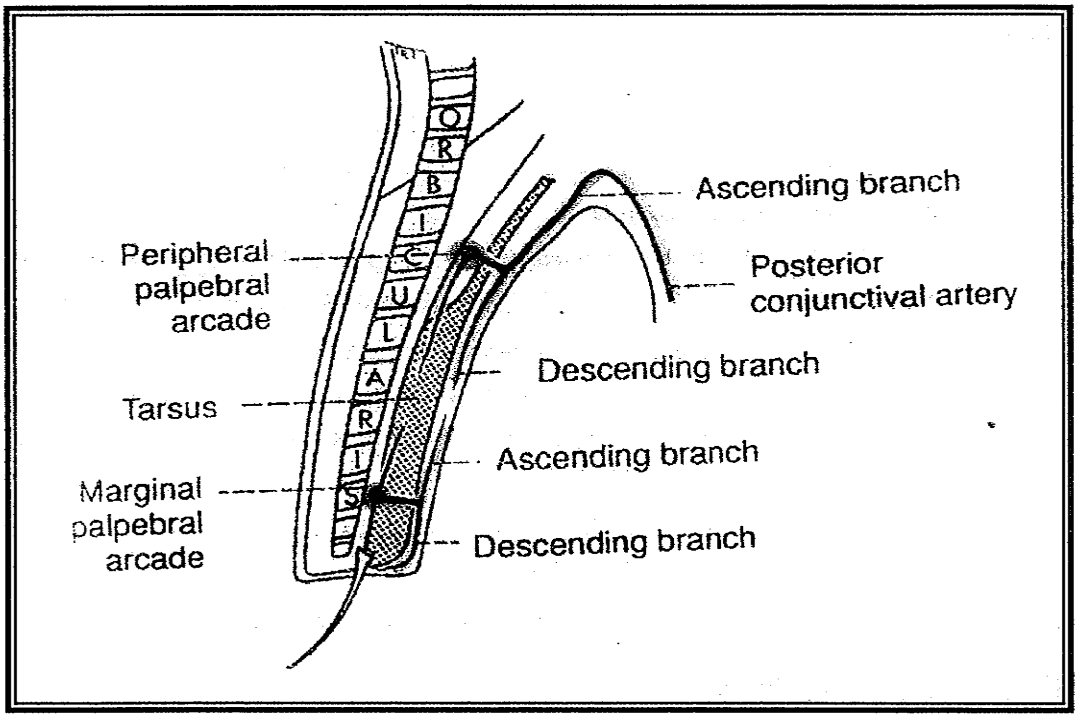
2) The glands of ***Wolfring***
   - Site:
     - ⇒ located deep in the substantia propria,
     - ⇒ **5** in the upper border of the upper tarsus & **2** in the lower border of the lower tarsus
   - Number: upper eyelid → **5** Lower eyelid → **2**
   - Function: accessory lacrimal glands. (larger than glands of Krause)

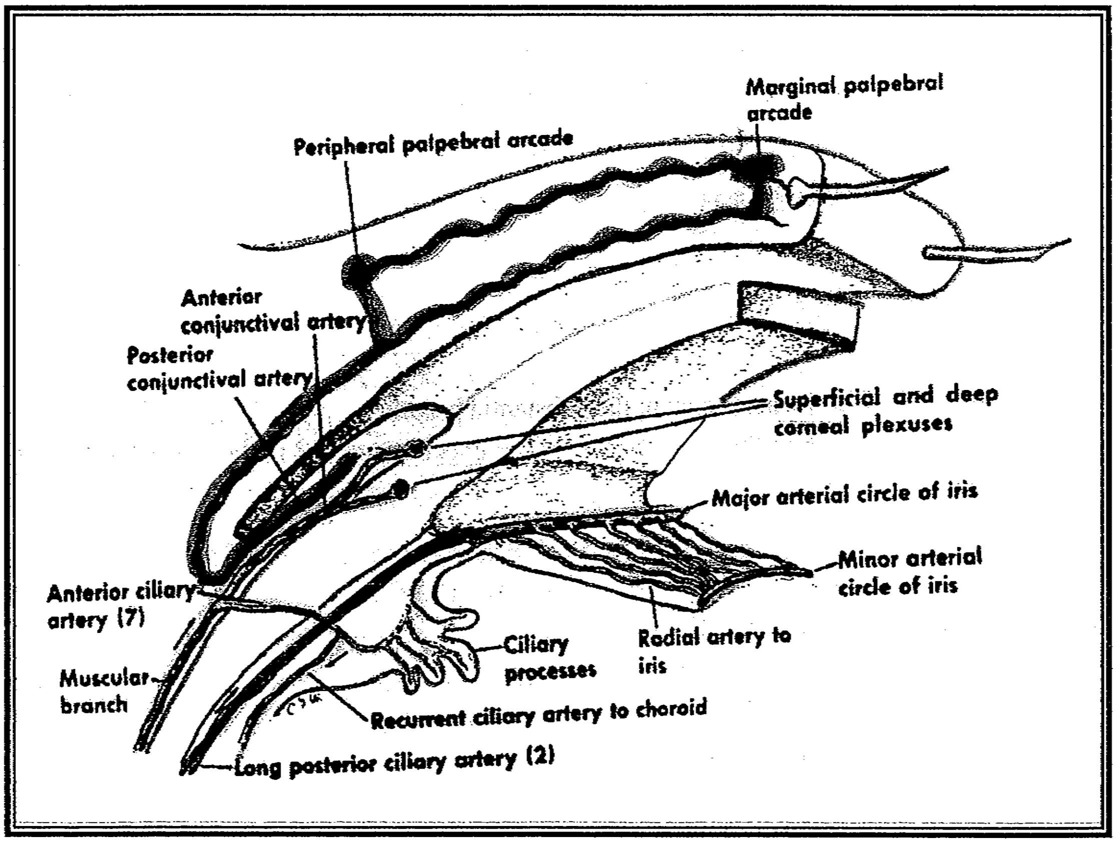
- The ***crypts of Henle***
  - Site:
    - ⇒ Between the tarsal plate & the fornices. (above and below the tarsal plates)
    - ⇒ **In the palpebral conjunctiva**
  - Structure: they are not true glands, but folds of conjunctival epithelium cut transversely

- ***Intra-epithelial glands of Tourneux***

  grouped goblet cells open into a narrow duct

- The glands of ***Manz*** → encircle the limbus (Evidence of their presence in human is a controverse)


ORBICULARIS
Ascending branch
Posterior conjunctival artery
Peripheral palpebral arcade
Descending branch
Tarsus
Ascending branch
Marginal palpebral arcade
Descending branch


Marginal palpebral arcade
Peripheral palpebral arcade
Anterior conjunctival artery
Posterior conjunctival artery
Superficial and deep corneal plexuses
Major arterial circle of iris
Minor arterial circle of iris
Anterior ciliary artery (7)
Muscular branch
Ciliary processes
Radial artery to iris
Recurrent ciliary artery to choroid
Long posterior ciliary artery (2)

□ **Blood Supply:** Arterial:

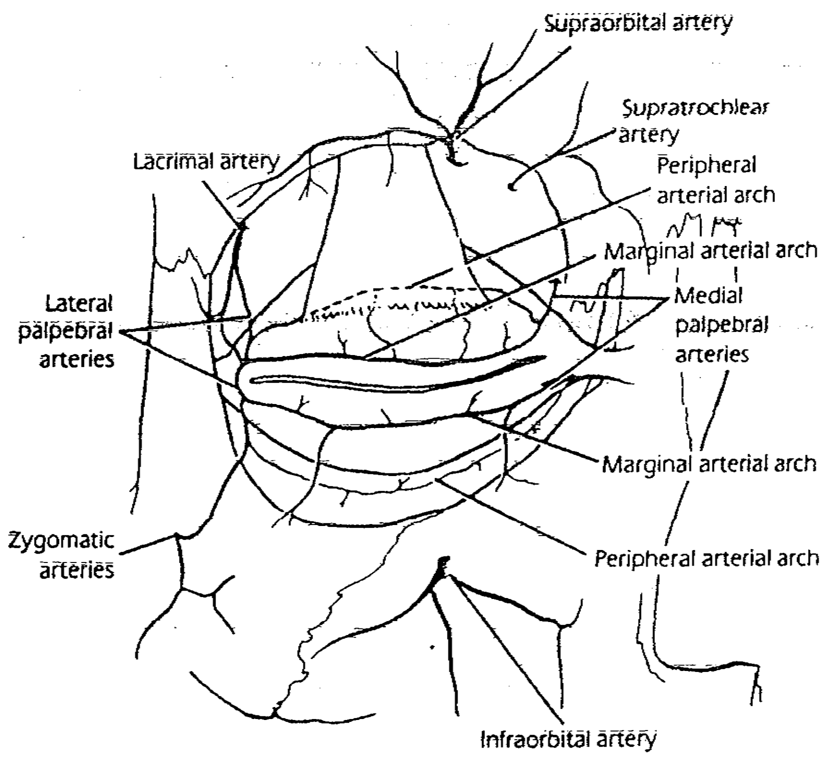
- Palpebral conjunctiva
  - **Marginal** & **tarsal** palpebral conjunctiva ⇒ **Marginal arterial arcade.**

➪ Sitiuated → 3 mm from the free lid margin between orbicularis oculi & tarsus
➪ Formed by → Anastomosis between ***medial & lateral palpebral as.*** (branches of ophthalmic)
➪ Gives: ➪ **Perforating branches**
(pierce the tarsus at sulcus subtarsalis)
then devides into
⇓ **Marginal arterioles** (run down to the lid margin)
⇓ **Tarsal arterioles** (short) (run up to anastomose with corresponding branch of peripheral arcade)

  - **Orbital** palpebral & **fornix** conjunctiva ⇒ **Peripheral arterial arcade.**

➪ Sitiuated in front of the upper margin of tarsus
➪ Gives: ➪ **Peripheral Perforating branches**
(pass over the tarsus pierce Muller muscle)
then devides into
⇓ **Ascending arterioles** (run up to the fornix)
descend under bulbar conjunctiva as
⇓ **Posterior conjunctival arteries**
(anastomose with Anterior conjunctival arteries)
⇓ **Descending Tarsal arterioles** (long) (run down to anastomose with corresponding branch of marginal arcade)

- Bulbar conjunctiva
  - Peripheral bulbar conjunctiva ⇒ **posterior conjunctival branches** of the peripheral arterial arcade
    - → Dilated in inflammation of the ***bulbar conjunctiva***.
    - → Extend under the bulbar conjunctiva till 4 mm of the corneoscleral limbus & are most evident in the fornices and fade towards the limbus.
    - → Because of their superficial position
      1) They appear bright red and move with the conjunctiva.
      2) They may be constricted on topical instillation of 1:1,000 epinephrine.
  - Circumcorneal bulbar conjunctiva ⇒ **anterior conjunctival branches** of the seven anterior ciliary arteries divide to form:
    - ⇒ *Superficial (conjunctival)* pericorneal plexus
      - → Dilated in inflammation of the ***cornea*** (superficial)
    - ⇒ *Deep (episcleral)* pericorneal plexus.
      - → Dilated in inflamation of the ***cornea*** (deep), ***iris***, ***ciliary body*** & in ***Angle closure glaucoma***.
      - → Extend till 4 mm of the corneoscleral limbus & are most evident near the limbus & fade towards the fornices.
      - → Because of their deep position
        1) They appear dusky red or purple and don't move with the conjunctiva.
        2) They are not constricted by topical epinephrine.


Supraorbital artery
Supratrochlear artery
Lacrimal artery
Peripheral arterial arch
Marginal arterial arch
Lateral palpebral arteries
Medial palpebral arteries
Marginal arterial arch
Zygomatic arteries
Peripheral arterial arch
Infraorbital artery

- Because of generous anastomoses between the anterior & posterior conjunctival arteries severe Inflammations always cause injection of both ciliary and conjunctival vessels.
- New vessels that invade the cornea come from Anterior ciliary arteries as they piercing the sclera to the ciliary body
- In the **lower eyelid**, the peripheral arterial arcade is usually absent → in this case the *palpebral conjunctiva*, *Fornix* & *lower part of bulbar conjunctiva* get blood supply from the ***marginal arcade*** or from ***muscular arteris to inferior rectus***

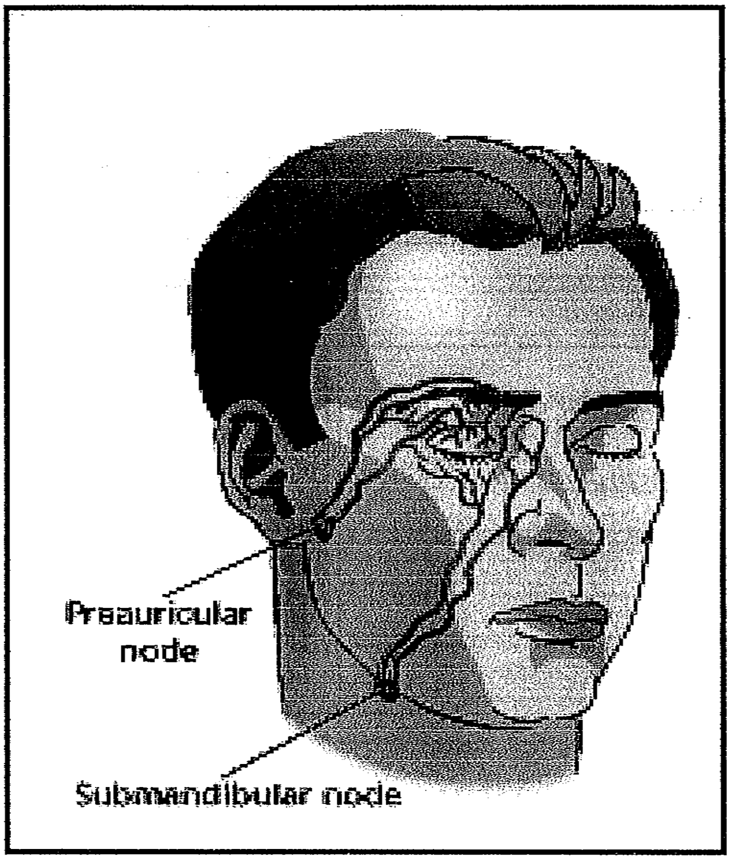
Ciliary injection	Conjunctival congestion
Injection of vessels from ***Anterior ciliary arteries*** *Anterior Conjunctival arteries*	Conjestion of vessels from ***palpebral arcades*** *Posterior Conjunctival arteries*
Circumcorneal 4 mm & ↓ towards fornices	***At fornices*** & ↓ towards cornea
Rose pink or ***dusky red*** (deep)	***Bright red*** (superficial)
Not constricted by topical epinephrine	***constricted*** by topical epinephrine
Doesn't move with conjunctiva	***Moves*** with conjunctiva
Doesnt fade on pressure	***Fades*** on pressure
In inflammation of ***Iris, Ciliary body & Cornea***	In Inflammations of ***conjunctiva*** (conjunctivitis)
A > V	V > A

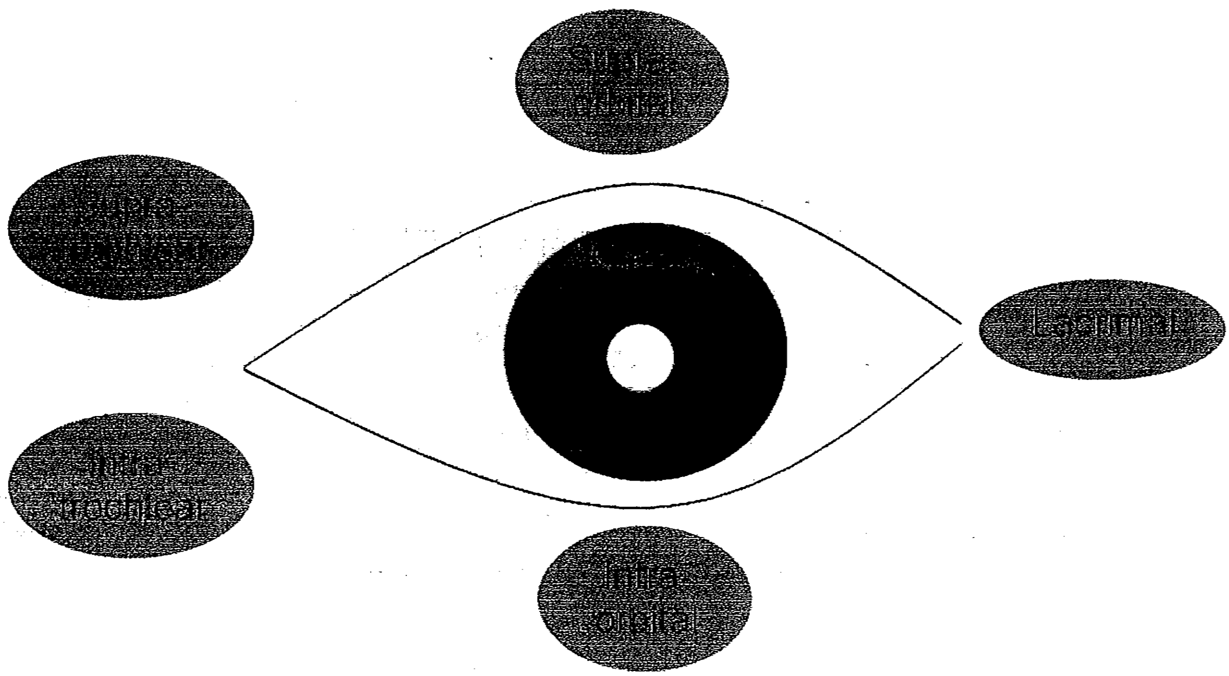
Venous:

Accompany but are much more numerous than the corresponding arteries

- Palpebral conjunctiva + Fornix + Peripheral major part of bulbar conjunctiva → **Palpebral venous plexus.** (between tendons of levator) → **Muscular veins** (of levator & SR) → **Ophthalmic v.**
- Circumcorneal bulbar conjunctiva → form netweork 5-6 mm wide → **Muscular veins** → **Ophthalmic v.**

Conjunctival veins drain into superior & inferior ophthalmic veins ⇒ This explains their gross dilataion in cavernous sinus thrombosis.


Preauricular
node
Submandibular node


Infra
trochlear
Lacrimal
Infra
orbital

☐ Lymphatic supply: parallel to those of the eyelid.

- Arranged into:
  - **Superficial plexus**: small vessels, present beneath the vascular capillaries
  - **Deep plexus**: Large vessels, present in the fibrous layer (it receives lymph from superficial plexus)
- Drained by two groups of lymphatic vessels:
  - **medial** group: drains the medial part ⇒ ***submandibular*** lymph nodes.
  - **lateral** group: drains the lateral part ⇒ ***preauricular*** & ***Superficial parotid*** lymph nodes.

Both of them ⇒ ***Upper deep cervical*** lymph nodes.

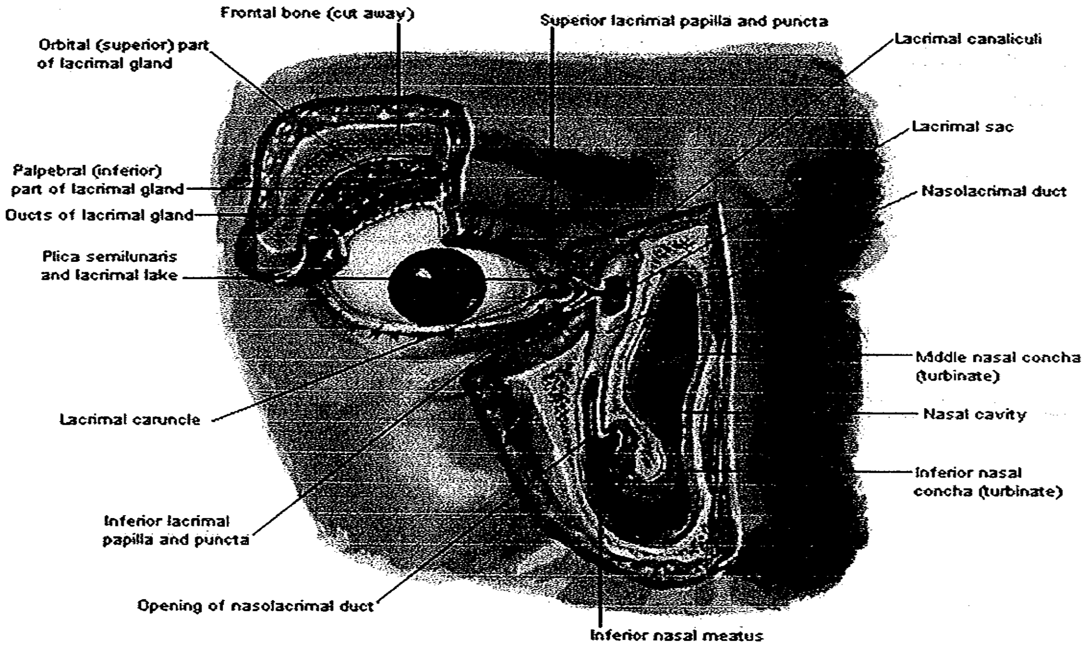
☐ Nerve supply:

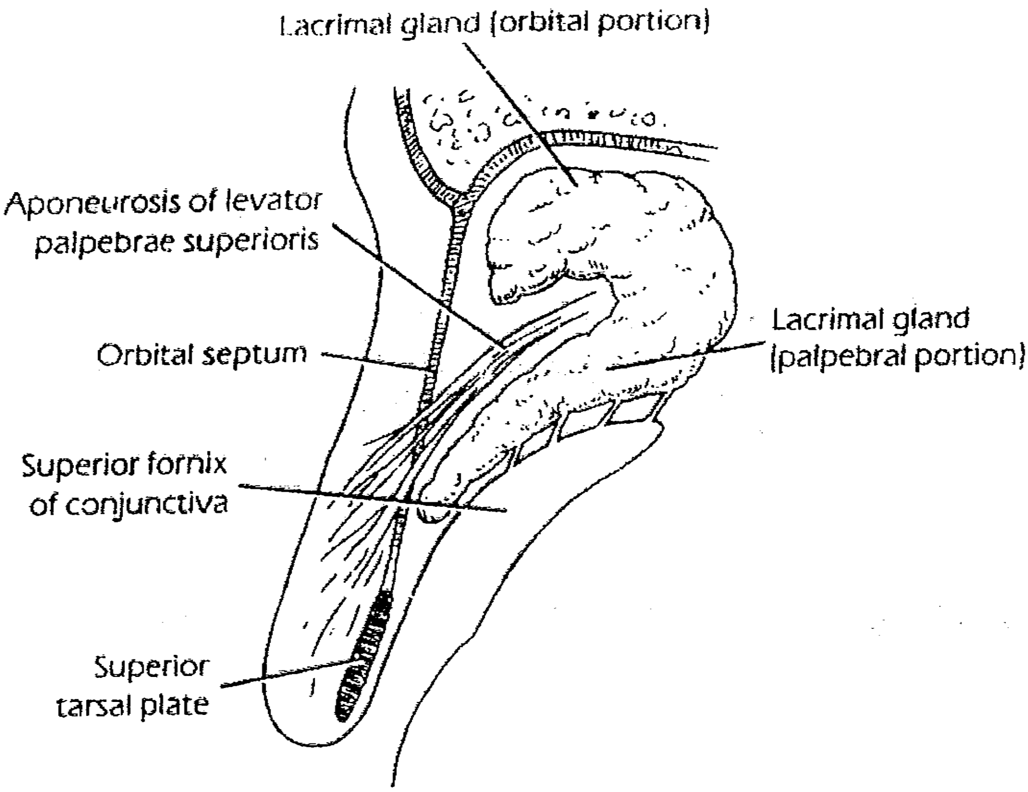
- **Sensory:**
  - Superior palpbral conjunctiva:
    - ⇒ Medially ⇒ ***Frontal n.*** *(Supratrochlear & Supraorbital ns)*
    - ⇒ Laterally ⇒ ***Lacrimal n.***
  - Inferior palpebral conjunctiva:
    - ⇒ Medially ⇒ ***Infraorbital n***. (From maxillary) & ***Infratrochlear n.*** (from nasociliary)
    - ⇒ Laterally ⇒ ***Lateral palpebral*** branch of Lacrimal n. (ophthalmic)
  - Pericorneal bulbar conjunctival:
    - ⇒ Branches of ***Long ciliary nerves***.
- **Sympathetic:** (accompanying the blood vessels) To the bulbar conjunctiva.

Nerve endings are either simple or specialized

Free nerve endings → nerves loose their myelin sheath → form ***subepithelial*** plexus in the superficial part of substantia propria → fibers pass to form ***intraepithelial*** plexus around the bases of epithelial cells → send nerve fibrils between cells

End bulbs of Krause (Concerned with cold stimulus) → **rounded bodies** has C.T envelop lined by endothelium & contains a central mass of fibrils. One or two nerve fibers loose their neurilemal & myelin sheath → enter the body → join the central mass


Frontal bone (cut away)
Superior lacrimal papilla and puncta
Lacrimal canaliculi
Orbital (superior) part of lacrimal gland
Lacrimal sac
Palpebral (inferior) part of lacrimal gland
Ducts of lacrimal gland
Nasolacrimal duct
Plica semilunaris and lacrimal lake
Middle nasal concha (turbinate)
Lacrimal caruncle
Nasal cavity
Inferior nasal concha (turbinate)
Inferior lacrimal papilla and puncta
Opening of nasolacrimal duct
Inferior nasal meatus


Lacrimal gland (orbital portion)
Aponeurosis of levator palpebrae superioris
Orbital septum
Lacrimal gland (palpebral portion)
Superior fornix of conjunctiva
Superior tarsal plate

LACRIMAL APPARATUS

Secretory Portion

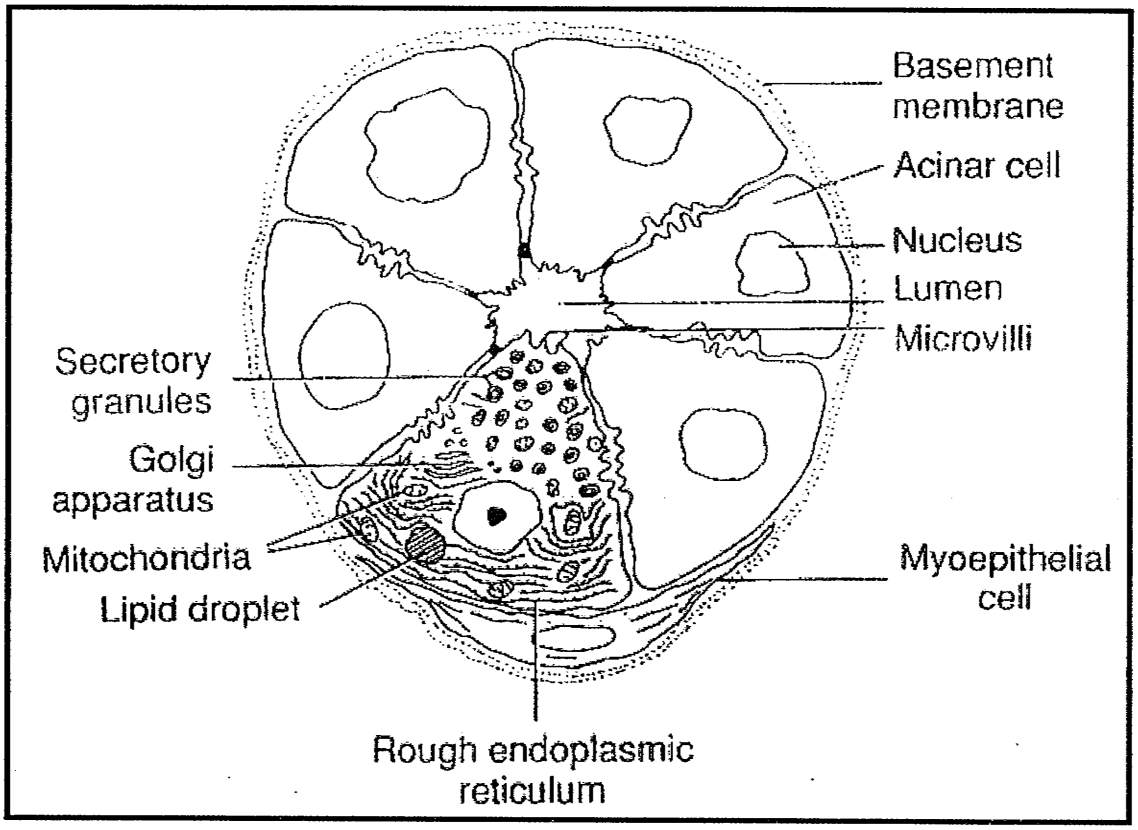
- **Accessory Lacrimal glands** (see before) ⇒ Basic secretion.
- **Main lacrimal gland** ⇒ Reflex secretion.

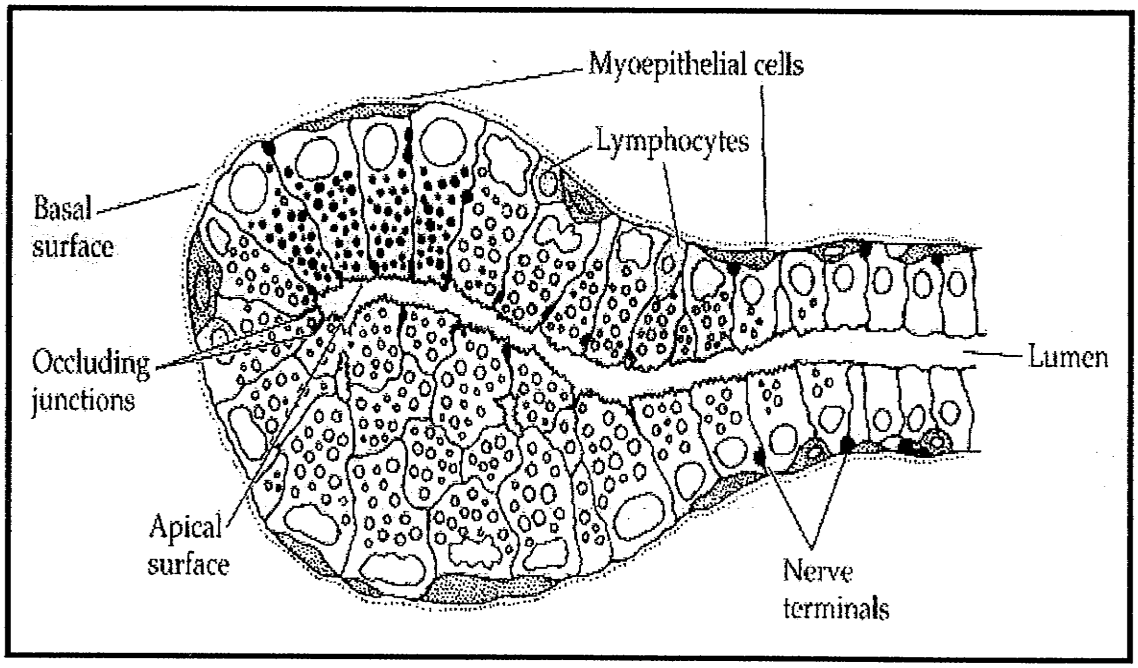
Gross Anatomy

- Size: **20 X 12 X 5** mm
- Weight: **75** gm
- Portions: the gland is devided by the lateral part of ***levator aponeurosis*** into:

	Orbital portion	**Palpebral portion**
Size	Larger	Smaller (⅓ of the orbital portion)
Site	Lacrimal gland fossa (in the anterior lateral part of the orbital roof)	In the lateral part of upper eyelid (can be seen through the conjunctiva when the upper lid is everted)
Shape	**Almond shaped** Superior surface → convex lies in the fossa connected to it by weak trabeculae Inferior surface → concave lies on the levator aponeurosis & LR Anterior border → Sharp in contact with the ***orbital septum*** (reached by division of skin. Orbicularis oculi & orbital septum) Posterior border → Rounded in contact with ***orbital fat*** Medial extremity → rests on levator Lateral extremity → rests on LR	**Flattened** from above downwards Anterior border → lies just above the lateral part of the superior fornix. Posterior border → continuous with the rest of the gland around the lateral border of the levator aponeurosis.

- Ducts:
  - ⇒ 3-5 ducts pass from the orbital portion through the palpebral portion to open into the superior fornix.
  - ⇒ 5-7 ducts from the palpebral portion open separately into the superior fornix → So, surgical removal of the palpebral part will destroy the whole gland.


Basement membrane
Acinar cell
Nucleus
Lumen
Microvilli
Secretory granules
Golgi apparatus
Mitochondria
Lipid droplet
Myoepithelial cell
Rough endoplasmic reticulum


Myoepithelial cells
Lymphocytes
Basal surface
Occluding junctions
Lumen
Apical surface
Nerve terminals

▫ Structure: *Tubulo-alveolar* (tubulo-acinar) gland.

- Consist of ***lobules*** (each about the size of pin head) formed of:

numerous *Acini*
(composed of a double layers of cells resting on B.M)
1. outer myoepithelial contractile cells
2. inner secretory cylindrical cells

⇩

surrounding a
central canal

⇩

open into
larger ducts
(intralobular then interlobular ducts)

⇩

open into
excretory ducts
(lined by columnar epithelium & have a fibrous coat)

> **Secretory cells**
> - Predominantly serous (some mucous)
> - Basal nuclei
> - Rich in RER, Golgi complex & mitochondria.

- Intralobular (between acini) & interlobular (between lobules) **C.T reticulum** is present containing Blood vessels, Nerve fibers, Plasma cells & lymphocytes (aggregate into follicles)

▫ Ligaments & support:

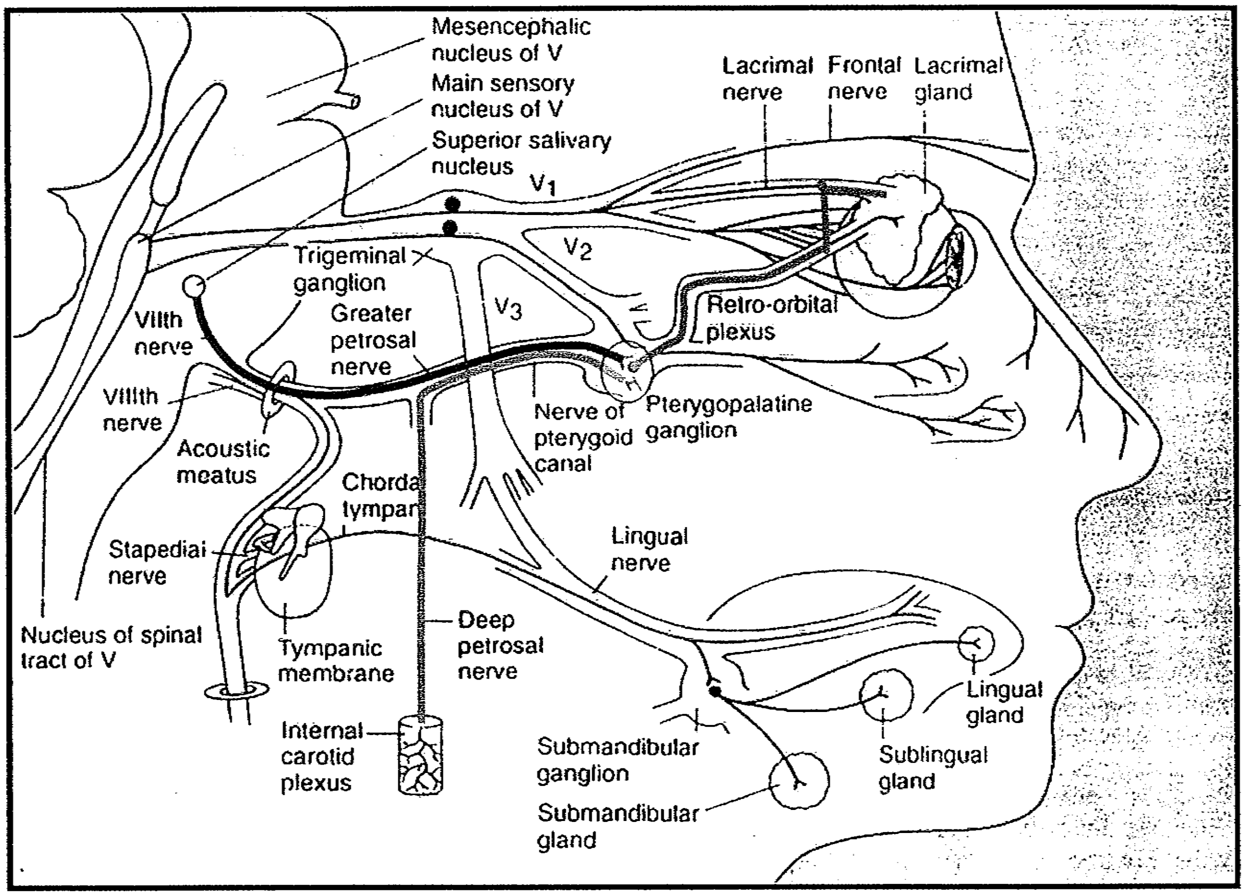
- **Superior** → to the lacrimal fossa = suspensory ligament
- **Inferior pole** → to zygomatic bone
- **Posterior** → where lacrimal nerve & vessels enter the periorbita
- **Internally** accompanying the ducts.

▫ Blood supply:

- **Arterial** → Lacrimal artery (enters the posterior border of the gland)
- **Venous** → Corresponding vein join the ophthalmic vein
- **Lymphatic** → Conjunctival lymphatics → Pre-auricular LNs

▫ Function: → Tears secretion (mainly the reflex secretion)

(Moisting the eye – Prevent friction between globe & lids – Keep the cornea transparent)


Mesencephalic
nucleus of V
Main sensory
nucleus of V
Superior salivary
nucleus
Lacrimal
nerve
Frontal
nerve
Lacrimal
gland
V1
V2
V3
Trigeminal
ganglion
VIIth
nerve
Greater
petrosal
nerve
Retro-orbital
plexus
VIIIth
nerve
Acoustic
meatus
Nerve of
pterygoid
canal
Pterygopalatine
ganglion
Chorda
tympani
Stapedial
nerve
Lingual
nerve
Nucleus of spinal
tract of V
Tympanic
membrane
Deep
petrosal
nerve
Lingual
gland
Internal
carotid
plexus
Submandibular
ganglion
Sublingual
gland
Submandibular
gland

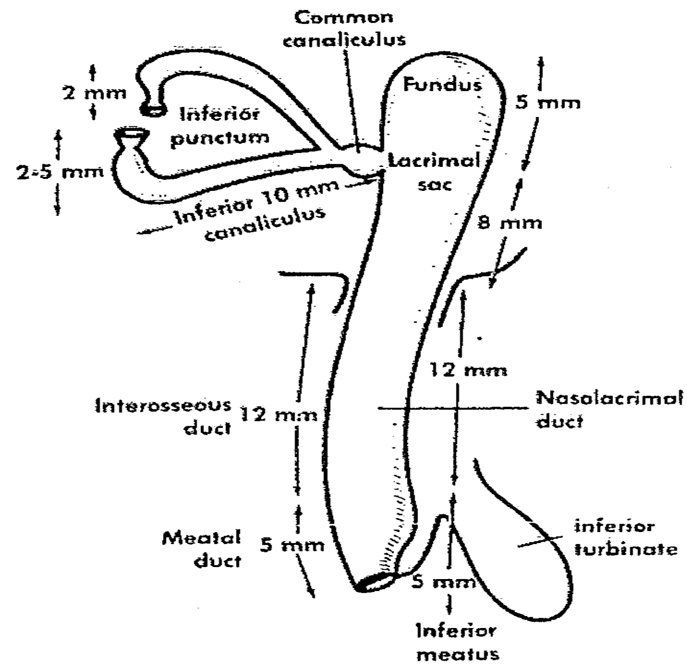
Nerve supply:

A. Parasympathetic	B. Sympathetic
lacrimal (Superior salivalory) nucleus (of the facial n. (N VII) in the floor of the 4th ventricle)	***Superior cervical sympathetic ganglion***
⇩	⇩
Preganglionic fibers extends with ***facial n.*** (nervus intermedius part)	Postganglionic fibers accompany **I.C.A.**
⇩	
geniculate ganglion (no relay)	
⇩	⇩
greater superficial petrosal n.	***Deep petrosal n.***
⇩	⇩
nerve of pterygoid canal	***nerve of pterygoid canal***
⇩	⇩
sphenopalatine ganglion (synapse)	***sphenopalatine ganglion*** (no relay)
⇩	⇩
*postganglionic parasympatheic fibers Join **maxilary n.** (of trigeminal)*	*postganglionic sympatheic fibers Join **maxilary n.** (of trigeminal)*
⇩	⇩
Zygomatico-temporal *branch*	***Zygomatico-temporal*** *branch*
⇩	⇩
Lacrimal n.	***Lacrimal n.***
⇩	⇩
Lacrimal Gland.	***Lacrimal Gland.*** (*Vasomotor*)

C. Sensory: → Lacrimal nerve.

Benign tumours (more common) → Slowly growing → fullness in the upper lateral part of upper eyelid → **displacement** of the globe (eg. Mixed cell tumour & Benign lymphoid hyperplasia)

Malignant tumours (less common) → Early erosion of lacrimal fossa → **severe pain** (eg. Malignant lymphoma & adenocarcinoma)


Common canaliculus
2 mm
Inferior punctum
2-5 mm
Inferior 10 mm canaliculus
Fundus
5 mm
Lacrimal sac
8 mm
12 mm
Nasolacrimal duct
Interosseous duct
12 mm
Meatal duct
5 mm
inferior turbinate
5 mm
Inferior meatus

Excretory Portion

Puncta:

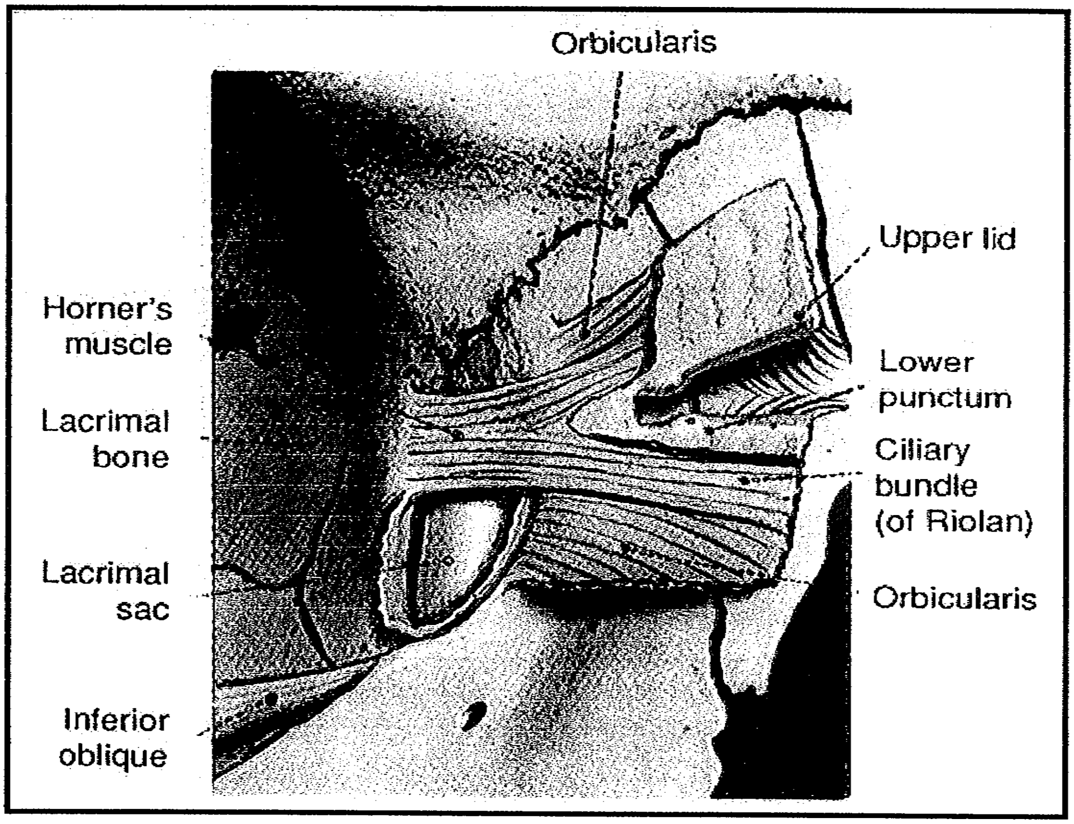
- Shape: slightly ***elevated***, ***rounded or slightly oval*** openings
- Diameter: About **0.3 mm**
- Site: on the upper & lower ***eyelid margins*** (at the junction of the ciliary & lacrimal portions), on the ***papilla lacrimalis***, *about* ***6mm*** *(upper) –* ***6.5mm*** *(lower)* ***from the medial canthus***
- The puncta openings of the lacrimal canaliculi are inverted into the lacrimal lake when the eyelids are closed.
- The puncta are surrounded by:
  - Dense, Fibrous, relatively avascular C.T. → Prevents their collapse + gives the pale colour
  - Orbicularis oculi muscle → Helps tear drainage

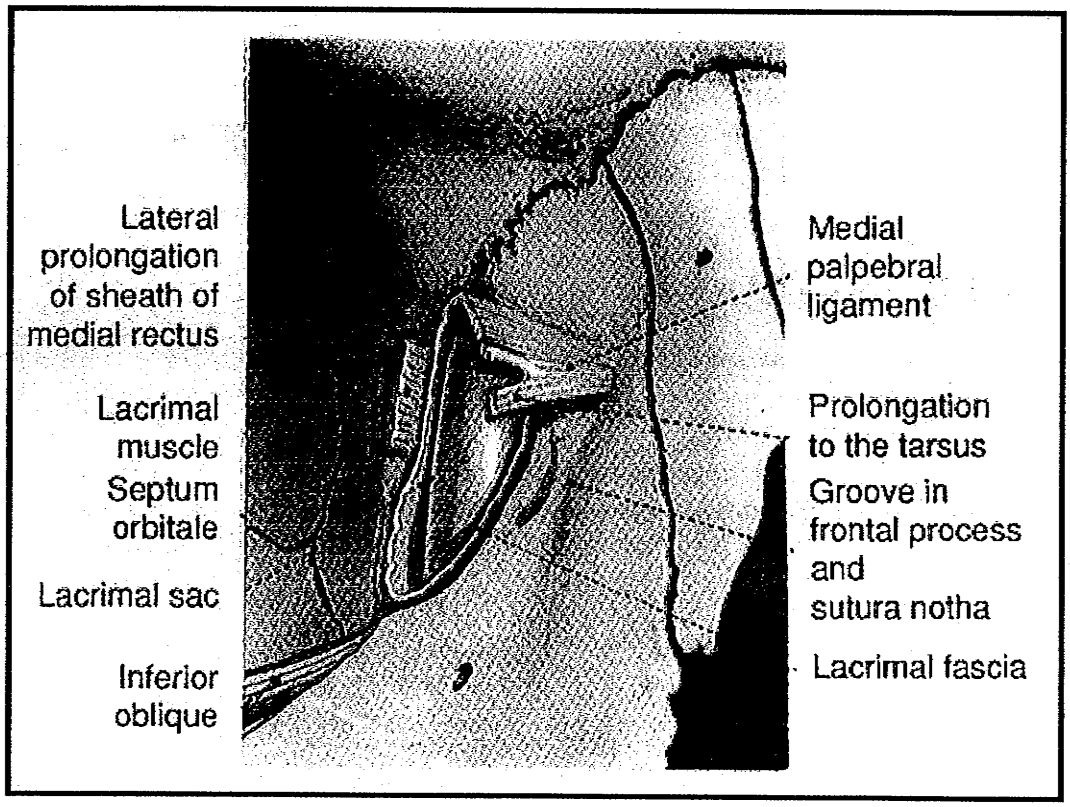
How to know its site ? ⇒ **6 mm** from the medial canthus + **0.5** mm from the tarsal gland + **elevated** + **paler** (avascular)

Canaliculi:

- The upper and lower canaliculi consist of:
  - **vertical portion** about 2 - 3.5 mm
  - **horizontal portion** about 8 mm (directed medially)

  ⇒ two join to Form, the **common canaliculus** → opens in the lacrimal sinus of Maier
- Diameter: About **0.5 mm.**
- Site: ***Lacrimal portion*** of the lid margin.
- Structure & surroundings:
  - Lined by ***stratified squamous epithelium.***
  - Surrounded by ***elastic tissue*** then ***orbicularis fibers.*** *(Horner's muscle)*


Orbicularis
Upper lid
Horner's muscle
Lower punctum
Lacrimal bone
Ciliary bundle (of Riolan)
Lacrimal sac
Orbicularis
Inferior oblique


Lateral prolongation of sheath of medial rectus
Medial palpebral ligament
Lacrimal muscle
Prolongation to the tarsus
Septum orbitale
Groove in frontal process and sutura notha
Lacrimal sac
Lacrimal fascia
Inferior oblique

☐ Lacrimal sac:

- **Site:** *lacrimal fossa* (in the anterior part of the medial orbital wall), between:
  1. the anterior lacrimal crest of the frontal process of the maxilla.
  2. the posterior lacrimal crest of the lacrimal bone.
- **Dimentions:** 15 X 5 X 5 (When distended)
- **Parts:** **Fundus** (above M.P.L) **Body** (behind M.P.L) **Neck** (continuous with NLD)

⇒ **Lateral sinus of Maier:** is a diverticulum that arise just behind the middle of the lateral surface (2.5 mm from the apex) → in which open the canaliculi.

- **Structure:**

A. Sac: Lined by 2 layers of columnar cells with goblet cells, surrounded by fibro-elastic CT

B. **Lacrimal fascia**:
- Formed by ***splitting of the periorbita*** into 2 layers at the posterior lacrimal crest → enclose the sac → meet again at the anterior lacrimal crest.
- ***Venous plexus*** is present between the lacrimal *sac* & lacrimal *fascia* (continuous with that around the duct)

- **Relations:**

A. Medial ⇒ ***Lacrimal bone*** separates the sac from
▫ ***anterior ethmoidal sinus** (above)* ▫ ***middle meatus of the nose** (below)*

B. Lateral ⇒ ***Skin*** ***Orbicularis oculi fibers*** ***Lacrimal fascia*** (few fibers of IO take origin from it)

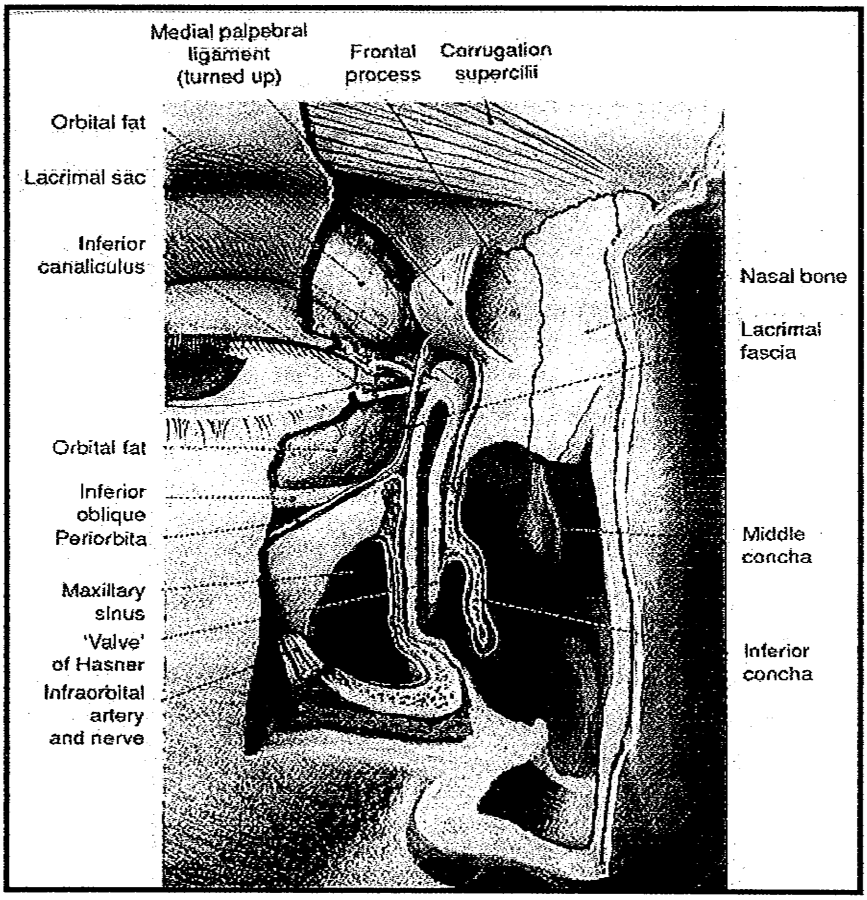
C. Posterior (From before backwards) ⇒ ***Lacrimal fascia*** → ***horner's ms*** → ***orbital septum*** → ***check ligament of medial rectus***

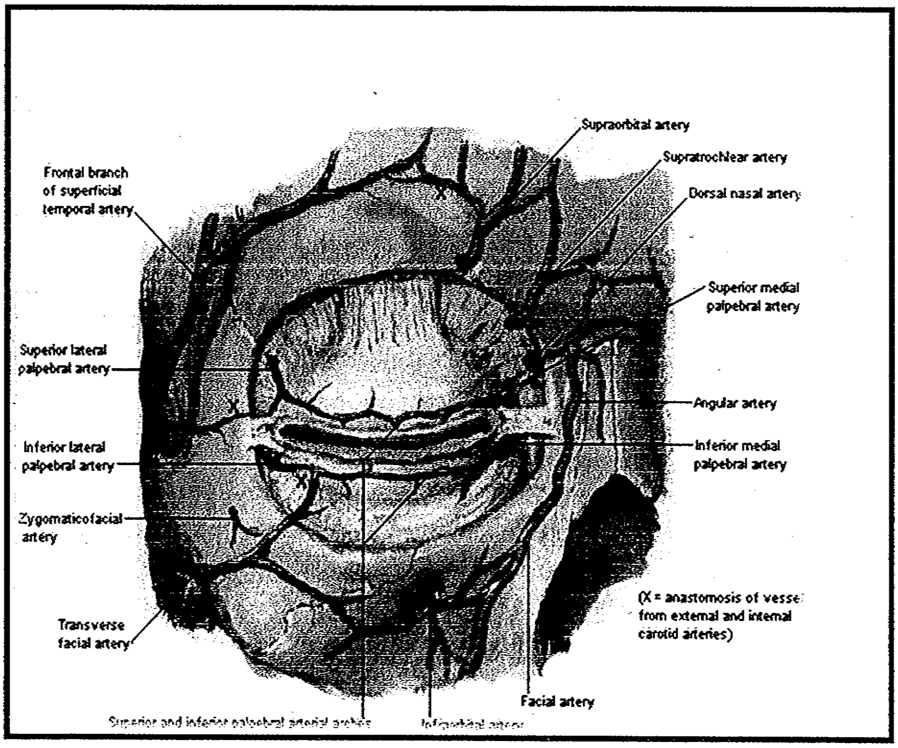
D. Anterior

1) ***Medial palpebral ligament*** Crosses the upper part of sac from medial to lateral
- Above it ⇒ The fundus of the sac rises 3-5 mm.
- Posterior to it ⇒ The body of the sac receives the canaliculi.
- Inferiorly ⇒ the neck of the sac is continuous with the nasolacrimal duct.

- The **upper border** blends with the lacrimal fascia → So slight blow to the eye may lead to lid swelling on blowing the nose ⇒
  How? Blow on the eye → strain on MPL → pull on the sac → tearing it → air pass from the tear to the lid tissue on blowing the nose (***surgical emphysema***)
- Below **lower border**, there is little resistance to distension of the sac (being only covered by few orbicularis oculi fibers & skin) → ***Abscesses & fistula*** will form here

2) ***Angular vein***
- Formed by union of **supratrochlear v. & supraorbital v.** → continues as **facial v.**
- It crosses MPL **8 mm** medial to the medial canthus → incision for sac removal should be either **6 mm** or **10 mm** from the medial canthus.


Medial palpebral ligament (turned up)
Frontal process
Corrugation supercilii
Orbital fat
Lacrimal sac
Inferior canaliculus
Nasal bone
Lacrimal fascia
Orbital fat
Inferior oblique
Periorbita
Middle concha
Maxillary sinus
'Valve' of Hasner
Inferior concha
Infraorbital artery and nerve


Supraorbital artery
Supratrochlear artery
Dorsal nasal artery
Frontal branch of superficial temporal artery
Superior medial palpebral artery
Superior lateral palpebral artery
Angular artery
Inferior lateral palpebral artery
Inferior medial palpebral artery
Zygomaticofacial artery
(X = anastomosis of vesse from external and internal carotid arteries)
Transverse facial artery
Facial artery
Superior and inferior palpebral arterial arches

Nasolacrirmal duct:

- **Definition:** A downward extension of the ***neck*** of lacrimal sac till the ***inferior nasal meatus*** (at the anterior portion of the lateral wall) (lateral to & below the inferior turbinate)
- **Length:** 15 – 18 mm
- **Site:**
  - In the ***bone of the nasolacrimal canal***
    - ⇒ formed by a groove on the maxilla & completed by lacrimal bone & lacrimal process of inferior concha
    - ⇒ The duct is loosely adherent to the canal above, but strongly adherent below → mucoperiosteum (infection is easily transmitted from bone to duct & vice versa)
  - The duct may pass for millimeters in the ***nasal mucous membrane*** before its opening
- **Direction:** ***Downwards***, ***Laterally*** & ***posteriorly*** (Massage → stretch & press down laterally & little back)

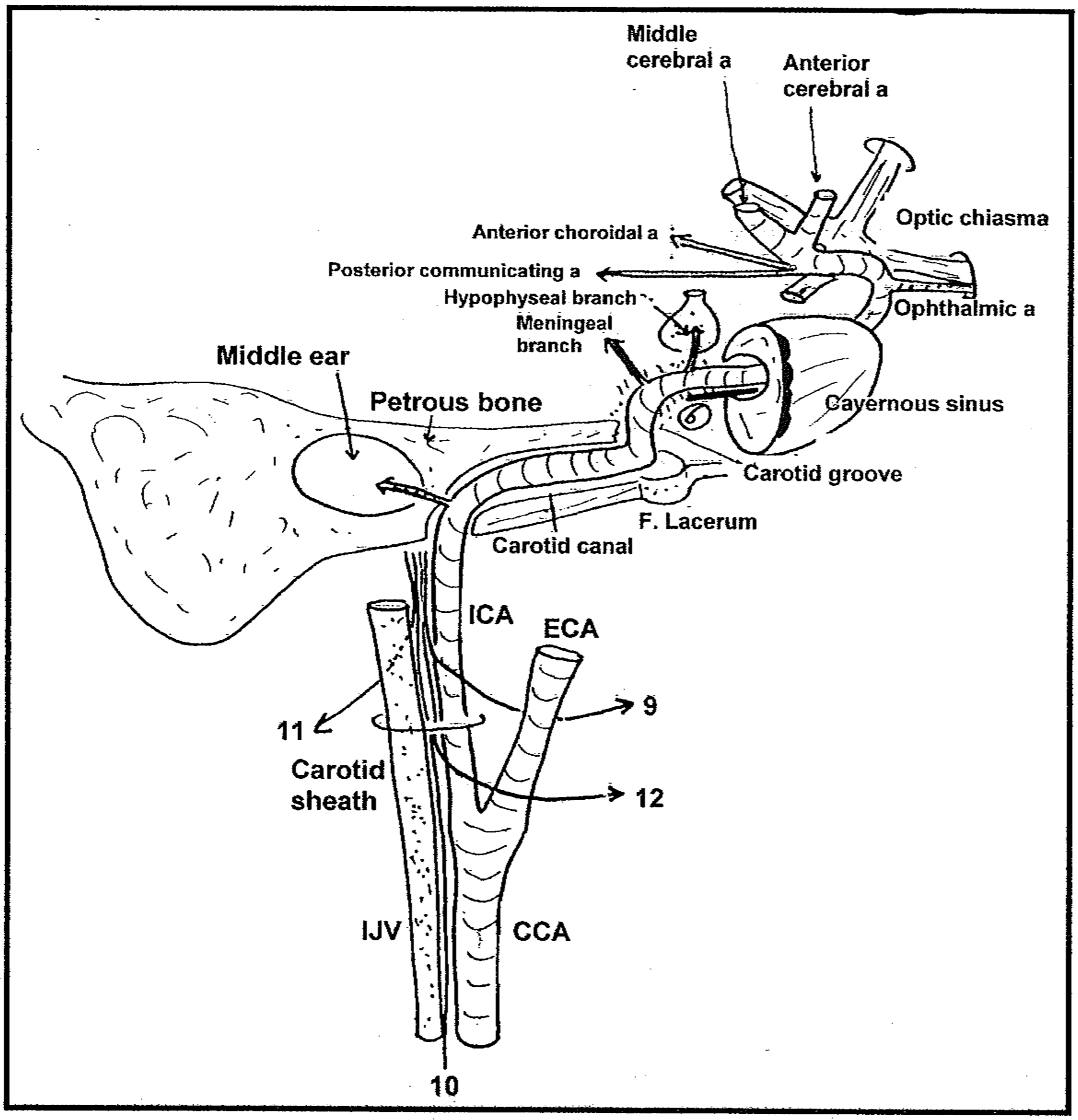
Surface anatomy → Line passing from the medial canthus to the upper 1st molar tooth

- **Valves:** ***numerous*** mucous membrane ***folds***, ***not valvular*** in function

Hasner's valve (guards the opening of the NLD) → prevent sudden blast of air from nose to the sac as during blowing the nose into a handkerchief)

- **Structure:**
  - ***Epithelium***: 2 layers
    - → Superficial columnar (reach the BM through deep cells) with goblet cells & mucous glands.
    - → Deep flattened.
  - ***Subepithelial layer***: contains lymphocytes
  - ***Fibroelastic*** membranous wall
  - ***Dense vascular erectile venous plexus*** surrounding the the duct (engorgement → duct obstruction)
- **Relations:**
  - Laterally ⇒ Maxillary antrum
  - Medially ⇒ Middle meatus of the nose
- **Blood supply:**
  - Arteries → ***Medial palpebral a.*** ***Angular a.*** ***Infraorbital a.*** ***Nasal br. of sphenopalatine***
  - Veins → ***Angular v.*** & ***Infraorbital v.*** (above) ***Nasal veins*** (below)
- **Lymphatic supply:** → ***Submandibular LNs***
- **Nerve supply:**
  - ***Infratrochlear n.*** (branch of ophthalmic)
  - ***Anterior superior alveolar n.*** (branch of maxillary)

> ➪ **In DCR we open the Lamina papyracea & the suture between lacrimal bone & frontal process of maxilla to form a fistula**
>
> ➪ **Before DCR** → ***X ray*** & ***CT scan***
> → ***ENT*** consultation → Ensure healthy mucosa
> → Exclude nasal causes (polyps, sinusitis, Antrum tumour & hypertrophied turbinate)



Middle cerebral a
Anterior cerebral a
Optic chiasma
Anterior choroidal a
Posterior communicating a
Hypophyseal branch
Meningeal branch
Ophthalmic a
Middle ear
Petrous bone
Cavernous sinus
Carotid groove
F. Lacerum
Carotid canal
ICA
ECA
9
11
Carotid sheath
12
IJV
CCA
10

BLOOD SUPPLY

A. ARTERIES

- **Ophthalmic** artery ⇒ The <u>globe</u> & the <u>orbital contents</u>.
- **External carotid** and **Ophthalmic** arteries ⇒ The <u>eyelids</u> and <u>conjunctiva</u>.

Internal Carotid Artery

The smaller of the 2 terminal branches of C.C.A. at the level of the upper border of thyroid cartilage (C_3). It ends in the cranial cavity lateral to the optic chiasma by dividing into anterior and middle cerebral arteries.

Its course is divided into 4 parts:

Cervical Part:

- This part ascends vertically in line with C.C.A. close to the side wall of pharynx to reach the carotid canal.
- The artery is ensheathed by the ***carotid sheath*** together with <u>I.J.V.</u> and <u>vagus n.</u> However, in the uppermost part, the I.J.V. and the last 4 cranial nerves are found behind the I.C.A.
- It gives no branches

Petrous Part:

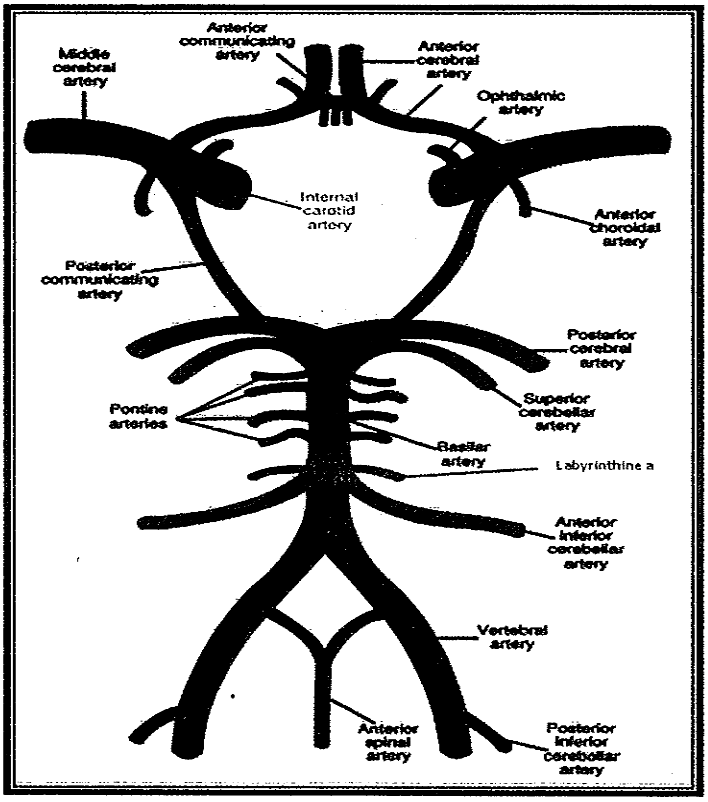
- In this part. the I.C.A. passes in the *carotid canal* which is an excavated passage inside the petrous bone in front of the middle and internal ear.
- The I.C.A. enters the post. end of the canal and leaves its ant. end (in the back of F. lacerum) to reach the cranial cavity.
- Inside the cavity, the I.C.A. passes first upwards, then forwards and medially.
- <u>*One branch*</u> *:* ***The carotico-tympanic a.*** → middle ear cavity.

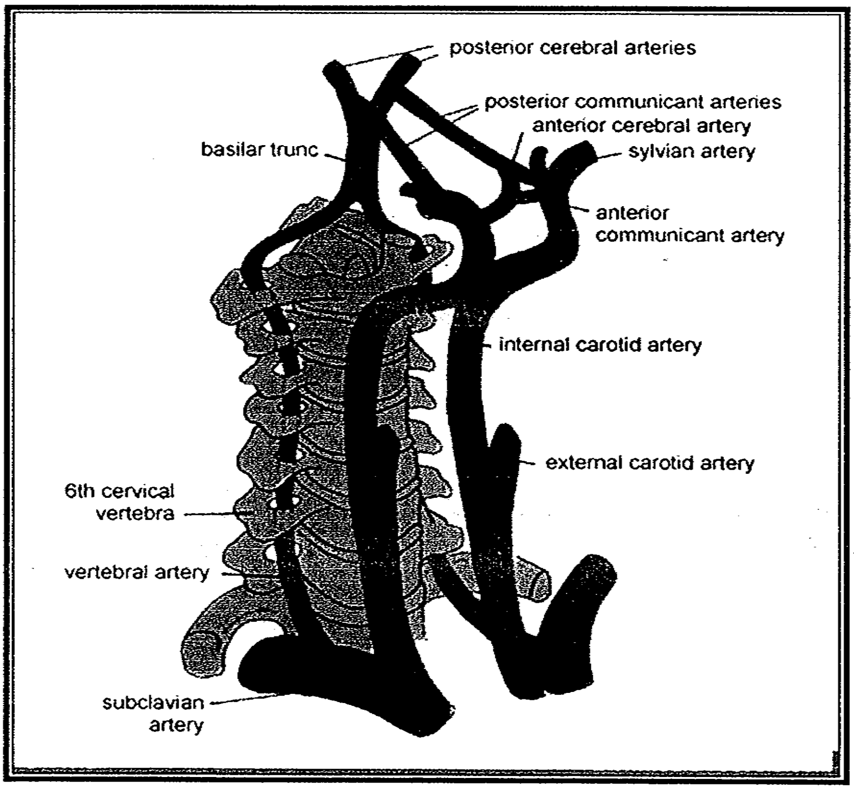
Cavernous Part:

- The I.C.A., after leaving its canal, pierces the back of the cavernous sinus → passes forwards inside the sinus (with the abducent n. inferolateral to it) grooving the side of body of sphenoid finally, it leaves the sinus by piercing its roof near the anterior end. (between 2nd & 3rd ns)
- <u>*Branches*</u> *:*
  - ***Meningeal branches.***
  - ***Hypophyseal arteries*** → pituitary gland.

Intracranial Part:

- After leaving the cavernous sinus, the I.C.A. curves backwards above the sinus (in the subarachnoid space) to become lateral to the optic chiasma where it gives its terminal branches.
- <u>*Branches*</u> *:*
  - ***Ophthalmic a.***
  - ***Anterior choroidal a.***
  - ***Posterior communicating a.***
  - ***Middle cerebral a.***
  - ***Anterior cerebral a.***


Anterior communicating artery
Middle cerebral artery
Anterior cerebral artery
Ophthalmic artery
Internal carotid artery
Anterior choroidal artery
Posterior communicating artery
Posterior cerebral artery
Pontine arteries
Superior cerebellar artery
Basilar artery
Labyrinthine a
Anterior inferior cerebellar artery
Vertebral artery
Anterior spinal artery
Posterior inferior cerebellar artery


posterior cerebral arteries
posterior communicant arteries
anterior cerebral artery
basilar trunc
sylvian artery
anterior communicant artery
internal carotid artery
external carotid artery
6th cervical vertebra
vertebral artery
subclavian artery

Vertebro-Basilar System

Two 4th parts of vertebral arteries uniting forming a basilar a.

Forth part of vertebral a.

- It enters the skull by passing through the F. magnum.
- It pierces the dura and arachnoid of the post. cranial fossa.
- It ascends in the subarachnoid space upwards and medially in front of the medulla oblongata.
- At the lower border of pons, it unites with the artery of the opposite side to form the basilar a.
- *Branches:*
  - ***Posterior spinal a.*** (the 1st branch).
  - ***Anterior spinal a.***
  - ***Posterior inferior cerebellar a.*** (the largest br.). → supplies:
    - → Lateral part of medulla oblongata.
    - → Choroid plexus of 4th ventricle.
    - → Part of inf. surface of cerebellum.

      Its obstruction → lateral medullary syndrome
  - ***Medullary brs*** → to the intermediate part of the medulla oblongata

The basilar a.

- Formed by union of the 4th parts of vertebral arteries at the lower border of pons.
- Ascends in the median groove ventral to pons.
- Ends at the upper border of pons by dividing into 2 post. cerebral arteries
- *Branches:*
  - ***Pontine brs.***
  - ***Anterior inferior cerebellar a.*** → part of inf. surface of cerebellum + caudal part of tegmentum of pons.
  - ***Superior cerebellar a.*** → sup. surface of cerebellum + rostral part of tegmentum of pons + colliculi of midbrain.
  - ***Internal auditory a.*** (labyrinthine a.) → internal auditory meatus → inner ear
  - Two ***posterior cerebral arteries*** (terminal brs.)

Circle of Willis

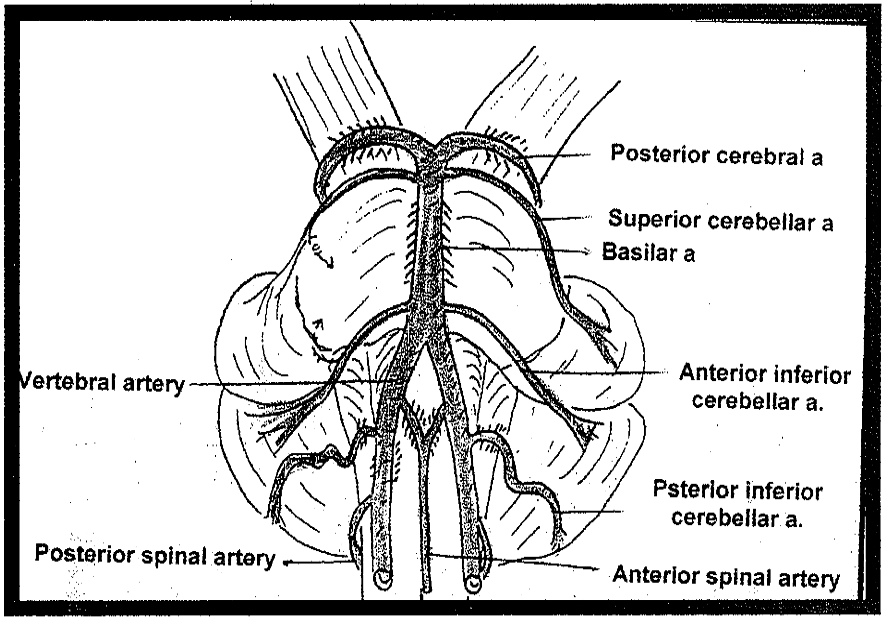
Definition: Arterial circle in the interpeduncular cistern surrounding the region of hypothalamus.

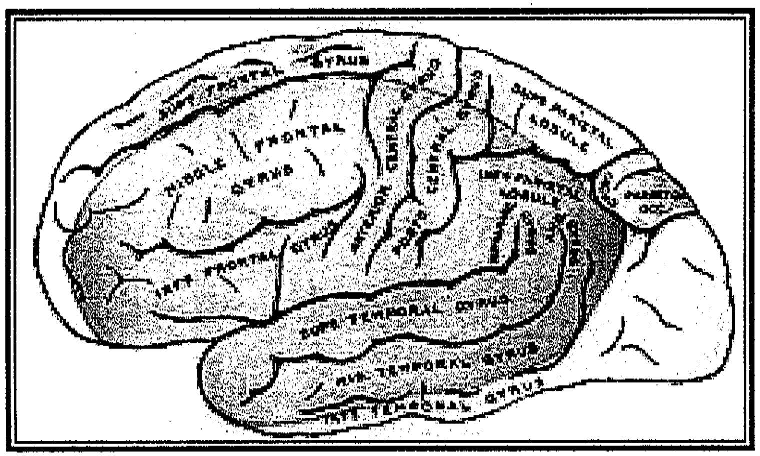
Formation:

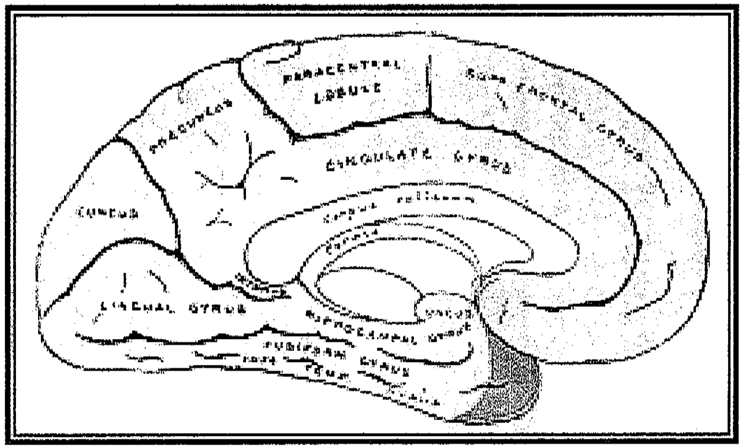
- Single anterior communicating a.: (bet. the 2 A.C.As.).
- Double (Rt. + Lt.) arteries:
  - A.C.A. I.C.A. P.C.A. Post. communicating a.

Functions:

- Supplies hypothalamus.
- Equalizes pressure in the sharing arteries.
- Collateral circulation in case of blockage of one of the sharing arteries.

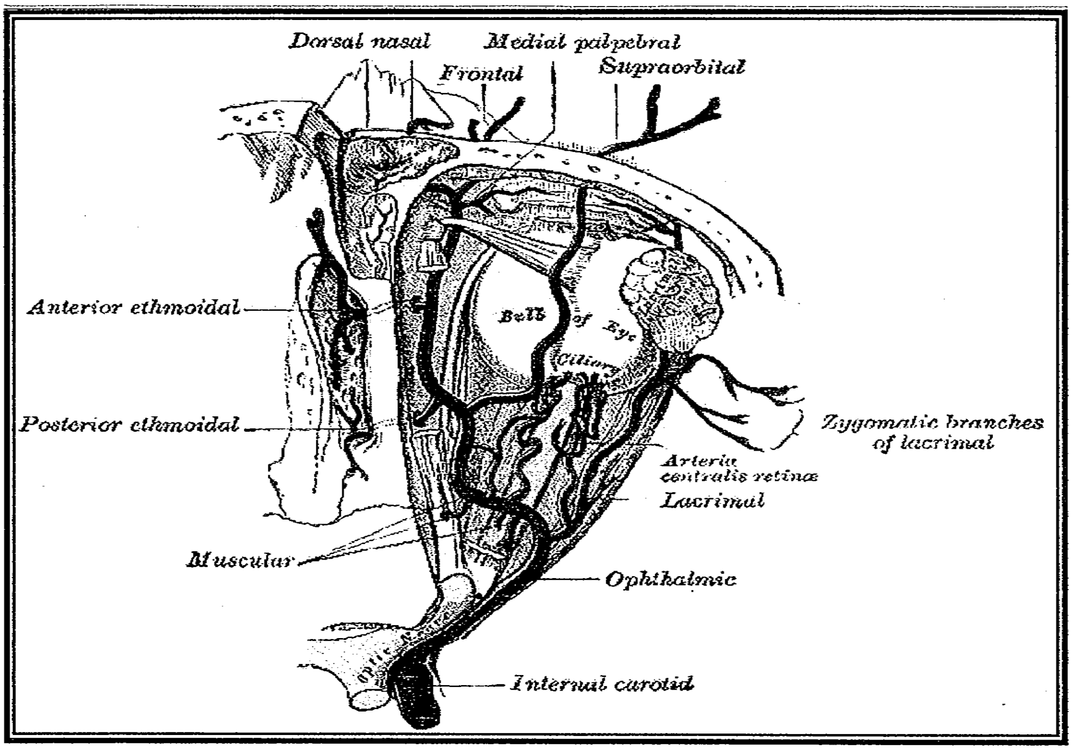

Posterior cerebral a
Superior cerebellar a
Basilar a
Vertebral artery
Anterior inferior cerebellar a.
Psterior inferior cerebellar a.
Posterior spinal artery
Anterior spinal artery



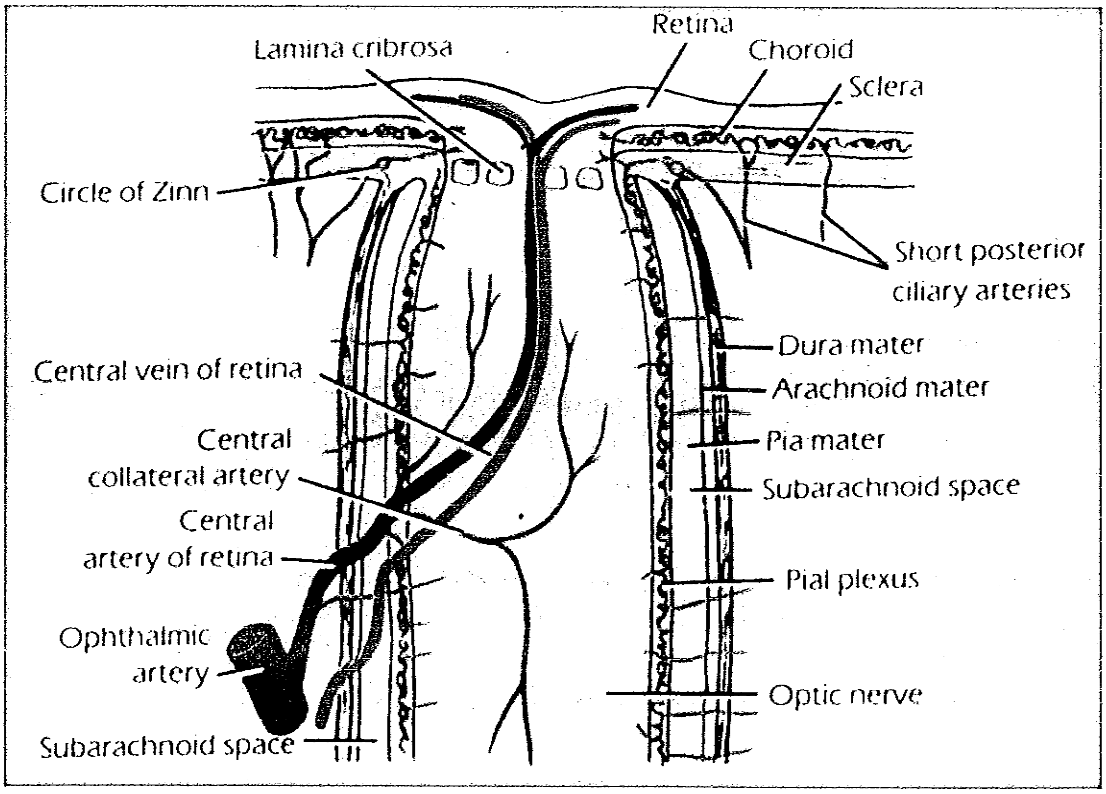

PARACENTRAL LOBULE
CINGULATE GYRUS
CUNEUS
LINGUAL GYRUS

Cerebral Arteries

Artery	Origin	Course	Branches		
			Central	cortical	Others
Anterior cerebral a. (A.C.A.)	The **smaller** of the terminal brs. of **I.C.A**	Passes forwards & medially above the optic n. → enters the long, cerebral fissure → runs backwards with the a. of the opposite side above corpus callosum lodged in the ***callosal sulcus*** The arteries of both sides are connected at their beginning by the **ant. communicating a.**	• They pass in the ant. perforated substance. • They supply: 1) Ant. part of corpus striatum. 2) Genu + lower $^1/_2$ of ant. limb of internal capsule. • The largest br. Is called ***Heubner's a.***	• **Medial** surface → all except the occipital lobe. • Inferior surface → medial ½ of orbital part. • Supero-lateral surface → the upper inch in front of the parieto-occipital sulcus. ***This means*** that the motor and sensory areas of the legs are supplied by A.C.A.	• Septal br. to the septal region. Lesion → ***prolonged unconsciousness.*** • Callosal br. to corpus callosum except splenium. Lesion → ***apraxia*** (no purposeful movements in spite of the intact ms.)
Middle cerebral a. (M.C.A.)	The **larger** of the terminal brs. of **I.C.A.**	It passes laterally in the ***stem* of Lat. sulcus** to enter the insula	• They pass in the ant. *Perforated substance* • They supply: - Post. part of corpus striatum. - Upper halves of both limbs of the int. capsule. • The longest br is called ***Charcot's a.*** (a. of cerebral Hge). It is the commonest a. to rupture → ***Hemiplegia.***	• Medial surface → nothing. • Inferior surface → temporal pole + lateral ½ of orbital part. • **Supero-lateral** surface → all except: o Occipital lobe. o Upper 1 inch. o Narrow strip at lower border of temporal lobe. ***This means*** that the M.C.A. supplies: → Motor & sensory areas except leg → Auditory area. → Broca's area. → Wernicke's area.	
Posterior cerebral a. (P.C.A.)	**Terminal** br. of **basilar a.**	It winds around the crus cerebri to run backwards lodged in the ***calcarine* sulcus.** It is connected to the I.C.A. by the posterior communicating a.	They pass in the *post. Perforated substance* to supply the thalamus and its related structures (subthalamus, epithalamus and metathalamus).	• Medial surface → occipital lobe. • Inferior surface → tentorial part except the temporal pole. • Supero-lateral surface → occipital lobe + narrow strip at lower border of temporal lobe. ***This means*** that the P.C.A. supplies: → Visual area. → Uncus **(smell center)**	• Brs. to cerebral peduncles. • Callosal brs. → splenium of corpus callosum • *Post. choroidal a.* → choroid plexuses of both lat. and 3rd ventricles.



Dorsal nasal
Medial palpebral
Frontal
Supraorbital
Anterior ethmoidal
Posterior ethmoidal
Muscular
Zygomatic branches of lacrimal
Arteria centralis retinæ
Lacrimal
Ophthalmic
Internal carotid



Retina
Lamina cribrosa
Choroid
Sclera
Circle of Zinn
Short posterior ciliary arteries
Dura mater
Arachnoid mater
Pia mater
Subarachnoid space
Central vein of retina
Central collateral artery
Central artery of retina
Pial plexus
Ophthalmic artery
Optic nerve
Subarachnoid space

Ophthalmic Artery

(Diameter = 2.8 mm)

Origin:

- The first intracranial branch of the ***internal carotid artery***
- From the medial side, just after the I.C.A. exits from the cavernous sinus.

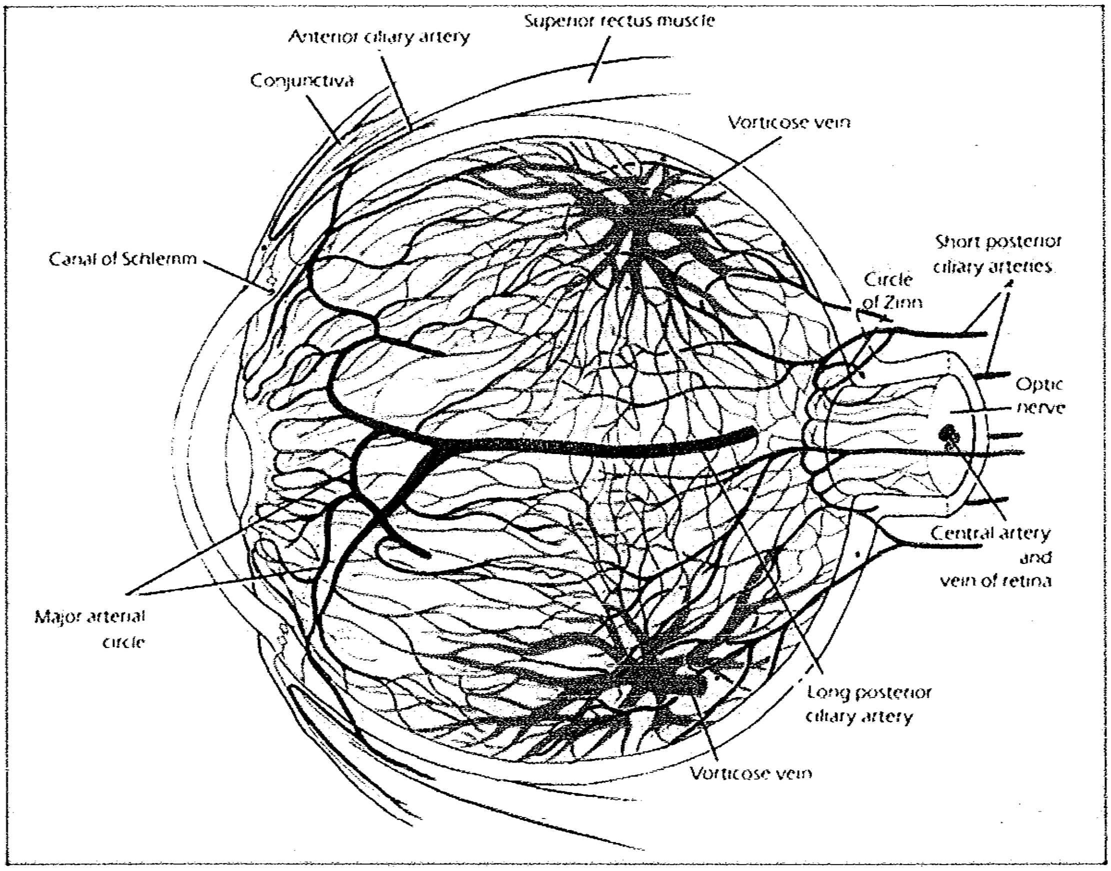
Course & Relations:

- **At its origin** → It is ***below the optic nerve*** & ***Lateral** to the anterior clinoid process.*
- **In the optic canal** → It is ***below & lateral** to the optic nerve*, ***within** optic nerve sheath.*
- **In the Orbit**
    1) Pierces the meningeal sheath
    2) Runs forward for a short distance inside the muscle cone *(**lateral** to optic n., **medial** to lateral rectus, abducent n., oculomotor n., Ciliary ganglion.*
    3) Turns medially *passing **over the optic n.*** (in 15% below it) to its medial side.
    4) Runs forward on the medial wall of the orbit (with the nasociliary nerve) between the *medial rectus **(below)*** & the *superior oblique **(above)***
- **Terminates** → At the *medial side of upper eyelid* by dividing into *dorsonasal* & *supratrochlear* branches.

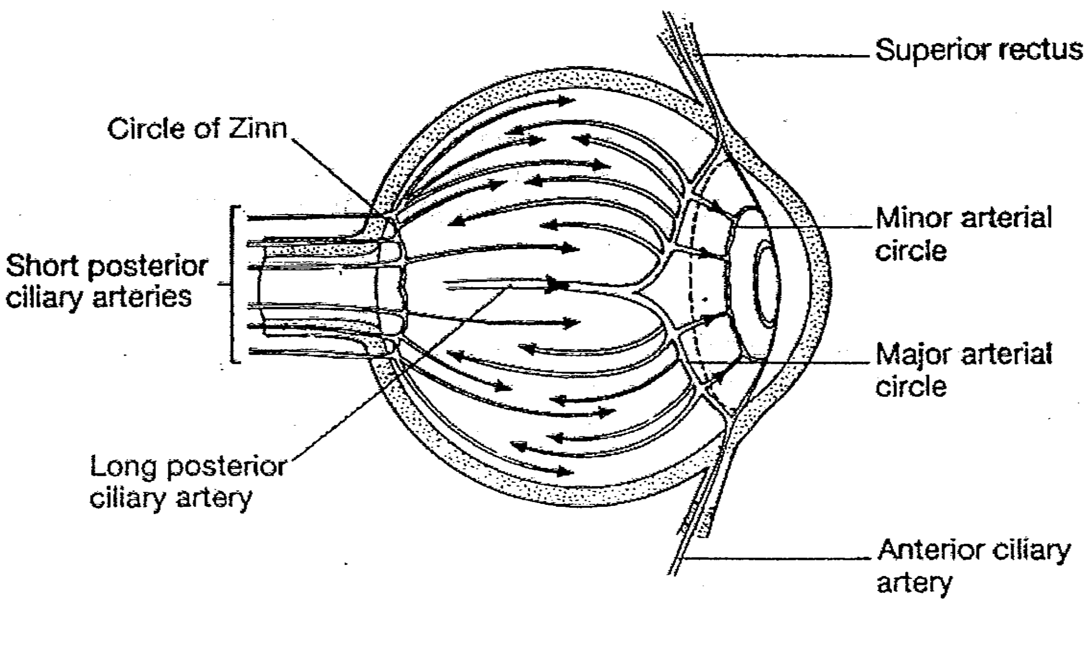
Branches: (The majority of branches of the ophthalmic a. are given off while the vessel is **lateral** to the optic n.)

1) The **central rential artery** sends nutrient vessels to the optic nerve, It then divides into superior and inferior optic disc branches (Papillary), which in turn divide into nasal and temporal branches that provide blood to the inner layers of the retina.

- **Origin**: the first branch of the ophthalmic artery.
- **Course**:
    1) Runs forwards in a wavy course, below optic n., Outside but adherent to dura.
    2) Pierces the dura and arachnoid sheaths → reach subarachnoid space.
    3) Pierces the inferio-medial side of the optic n. about **12 mm** posterior to the globe.
- **Termination**: It extends forward to the optic disc, where it bifurcates into superior and inferior papillary branches.
- As the vessel passes through the lamina cribrosa, its wall is reduced to about half its previous thickness, the internal elastic lamella is lost, and the medial muscle coat becomes incomplete. so its major branches within the eye are arterioles & not arteries
- **Branches**:
    1) Small Pial branches → as it pierces the pia mater
    2) Central collateral branches → as it pierces the optic n. (it passes with the CRA to the lamina cribrosa & it gives a branch that pass posteriorly in the optic n. to supply macular fibers.)
    3) Terminal branches.



Superior rectus muscle
Anterior ciliary artery
Conjunctiva
Vorticose vein
Canal of Schlemm
Short posterior ciliary arteries
Circle of Zinn
Optic nerve
Central artery and vein of retina
Major arterial circle
Long posterior ciliary artery
Vorticose vein



Superior rectus
Circle of Zinn
Minor arterial circle
Short posterior ciliary arteries
Major arterial circle
Long posterior ciliary artery
Anterior ciliary artery

2) The **<u>ciliary arteries</u>** : Arise as 2 trunks (while the ophthalmic a. **below** the optic n.) that give:

⇒ ***<u>Short posterior ciliary arteries</u>*** 6-20 arteries that enter the globe to be distributed to the *<u>choroid</u>* & optic *<u>disc</u>*.

- <u>Originate</u> as two or three branches of the ***ophthalmic artery***.
- These branches <u>subdivide</u> into 10 to 20 branches that perforate the sclera around the circumference of the optic nerve.
- Some of them <u>anastomose</u> to form the ***<u>vascular circle of Zinn</u>*** (circulus vasculosus nervi optica) around the optic disc in the sclera → gives the following branches:

1- Backwards → to the *<u>pial</u>* network.
2- Forwards → to the *<u>choroid</u>* (as far as the equator)
3- Inwards → *<u>optic disc</u>* + area of the retina surrounding the optic nerve → one of these branches may be large (The ***<u>cilio-retinal artery</u>*** ⇒ macula)

⇒ ***2 <u>Long posterior ciliary arteries</u>*** → penetrate the sclera on both sides of the optic n. → pass in the suprachoroidal space to the ciliary body → anastomose with the anterior ciliary arteries to form the circulus arteriosus iridis major.

- <u>Originate</u> as 2 branches of the ***ophthalmic artery***
- <u>Penetrate</u> the sclera just medial & lateral to the optic nerve.
- They <u>extend forward</u> in the suprachoroidal space (between the choroid and the sclera) on the medial and lateral sides of the globe to the ciliary body.
- There each <u>divides</u> into two branches that extend circumferentially to form the ***<u>Circulus arteriosus iridis major</u>*** that is located in the ciliary body.
  - ➪ Branches extend anteriorly to the iris
  - ➪ Recurrent choroidal branches extend posteriorly (as far as the equator)

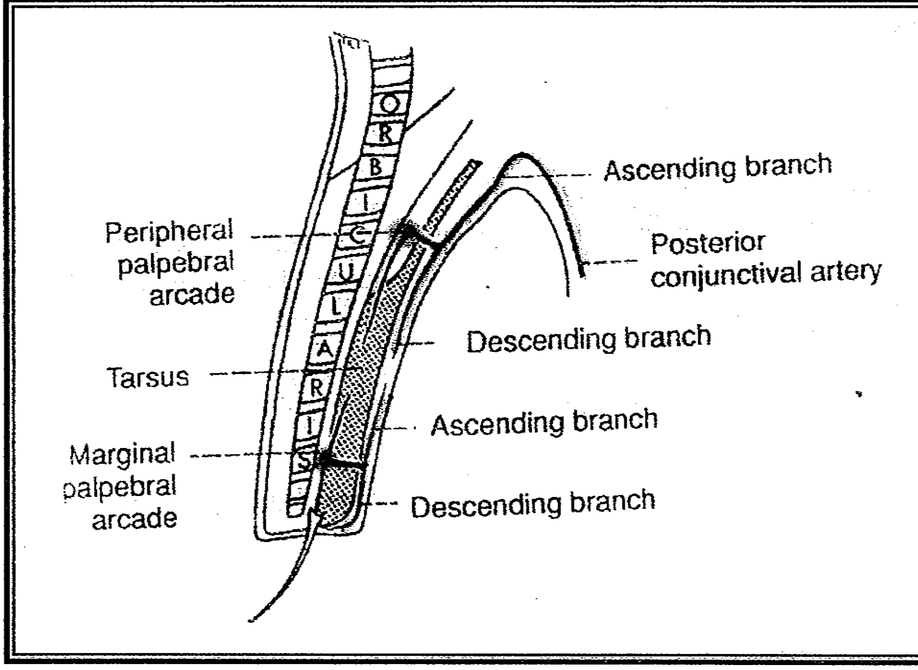
2) **<u>Muscular branches</u>** from *ophthalmic a.*.(medial & lateral) + *Lacrimal a.* + *Supraorbital a.*
- o Medial muscular branch ⇒ IR, IO, MR (larger) (as inf. devision of oculomotor)
- o Lateral muscular branch ⇒ LR, SR, SO, LPS

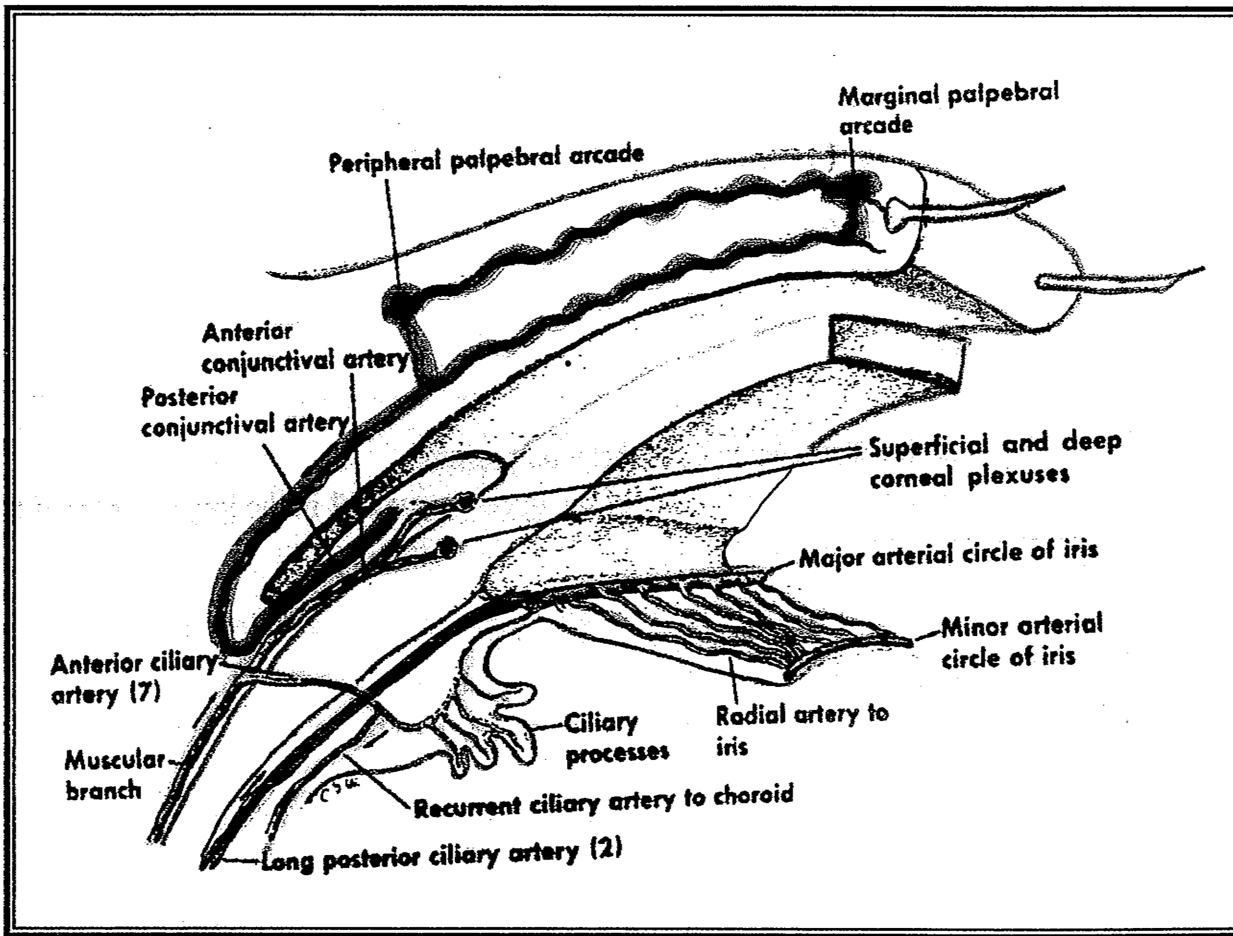
<u>Anterior ciliary arteries</u>

- Are the terminal branches of the two muscular arteries of each rectus muscle (except the lateral rectus muscle which has one muscular artery).
- The anterior ciliary arteries bifurcate into vessels that penetrate the sclera and noupenetrating vessels that extend towards the cornea.

→ The <u>penetrating vessels</u>
- ➪ provide the blood supply to the ***<u>ciliary body</u>***
- ➪ send ***<u>recurrent</u>*** branches to the anterior extremity of the choriocapillaris.
- ➪ send branches to the ***<u>Circulus arteriosus iridis major</u>***.

→ The <u>nonpenebating</u> vessels
- ➪ extend forward in the episclera as ***<u>anterior conjunctival arteries</u>***,
  - anastomose with posterior conjunctival arteries through recurrent branches
  - terminate in the superficial (conjunctival) & deep (episcleral) pericorneal plexus


O R B I C U L A R I S
Ascending branch
Peripheral palpebral arcade
Posterior conjunctival artery
Descending branch
Tarsus
Ascending branch
Marginal palpebral arcade
Descending branch


Marginal palpebral arcade
Peripheral palpebral arcade
Anterior conjunctival artery
Posterior conjunctival artery
Superficial and deep corneal plexuses
Major arterial circle of iris
Minor arterial circle of iris
Anterior ciliary artery (7)
Radial artery to iris
Ciliary processes
Muscular branch
Recurrent ciliary artery to choroid
Long posterior ciliary artery (2)

3) The **lacrimal artery** → Arises from ophthalmic a. **Lateral** to the optic n. → passes forward on the upper border of lat. Rectus (with lacrimal n.) → lacrimal gland

- ***Zygomatic***
- ***Lateral Palpebral arteries***

⇒ anastomose with medial palpebral arteries to form ⇒ peripheral and marginal palpebral arterial arcades.

4) **Medial palpebral arteries**: (from *ophthalmic a.* or *dorsal nasal a.)*

⇒ (usually 2 for each eyelid) anastomose with lateral palpebral arteries to form ⇒ peripheral and marginal palpebral arterial arcades.

5) **Recurrent meningeal artery** ⇒ superior orbital fussure ⇒ cranial cavity ⇒ Anastomoses with the middle meningeal branch of the maxillary artery (the terminal branch of the external carotid artery)

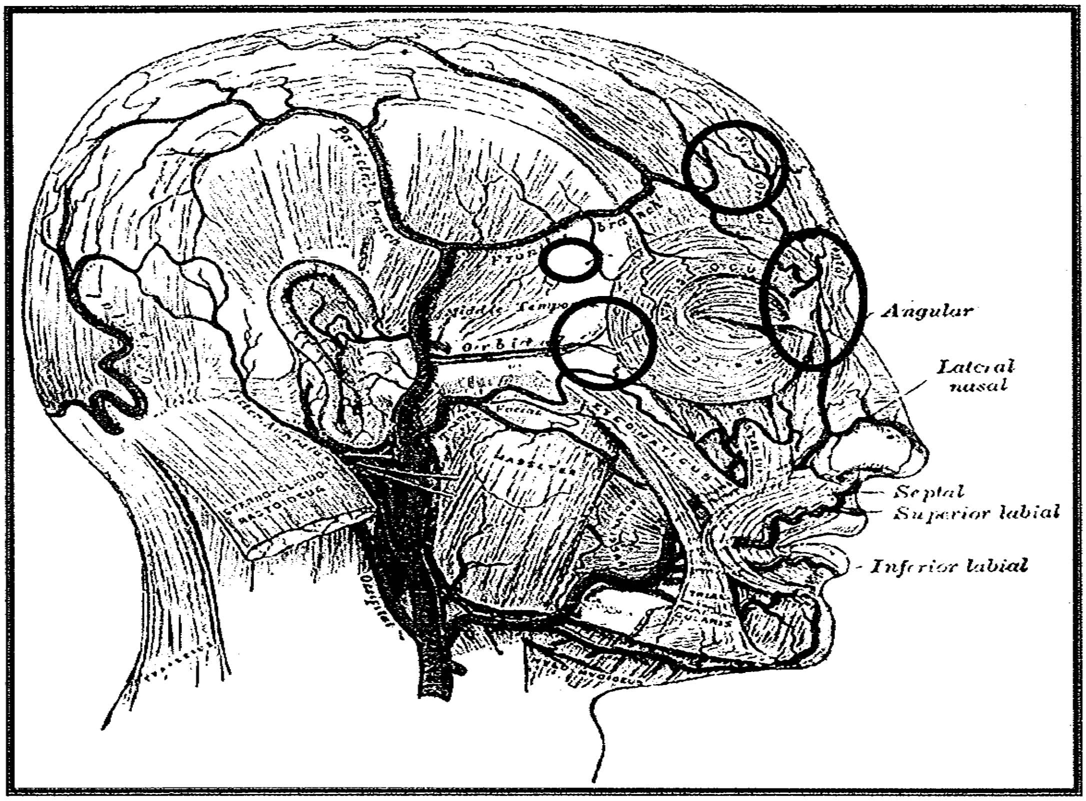
6) **Ethmoidal arteries:** As the ophthalmic artery courses medial to the optic nerve it gives off the anterior and posterior ethmoidal arteries

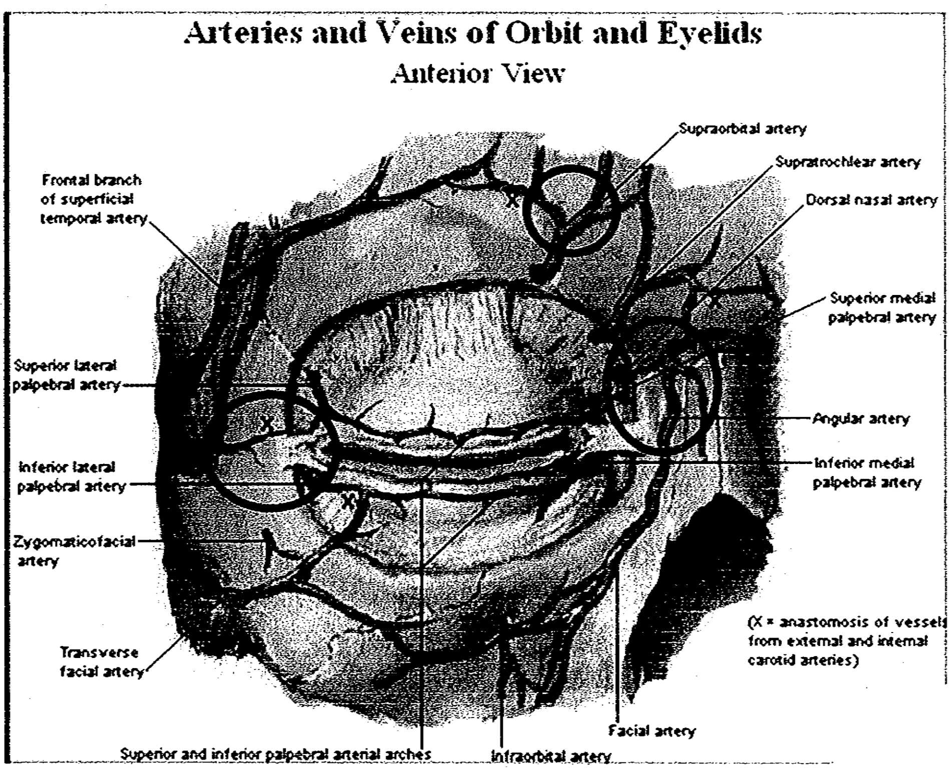
- The ***anterior ethmoidal artery***. supplies:
  - Dura → through the *recurrent(anterior) meningeal a.*
  - Mucosa of Anterior & middle ethmoidal sinuses & nose (anterior part)
  - Skin of nose.
- The ***posterior ethmoidal artery***. Supplies:
  - Mucosa of Posterior ethmoidal sinus & nose (upper part)

7) The **supra-orbital artery** arises from the ophthalmic a. **superior** to the optic n. → runs forward (with the supra-orbital n.) → ***supra-orbital foramen*** (or notch) → anastomose with the *superficial temporal* and *supra-trochlear* arteries in the scalp.

8) Termial branches:

- ***Dorsonasal artery***:
  → Pierces the orbital septum above the M.P.L
  → Supplies *skin of the root of the nose* + *Lacrimal sac*.
  → anastomoses with the angular artery (the terminal branch of the facial artery)
- ***Supratrochlear artery***:
  → Pierces the orbital septum
  → supplies the ***medial part of the forehead & scalp***.


Angular
Lateral nasal
Septal
Superior labial
Inferior labial


Arteries and Veins of Orbit and Eyelids
Anterior View
Supraorbital artery
Supratrochlear artery
Dorsal nasal artery
Frontal branch of superficial temporal artery
Superior medial palpebral artery
Superior lateral palpebral artery
Angular artery
Inferior lateral palpebral artery
Inferior medial palpebral artery
Zygomaticofacial artery
Transverse facial artery
(X = anastomosis of vessels from external and internal carotid arteries)
Facial artery
Superior and inferior palpebral arterial arches
Infraorbital artery

External Carotid Artery

The blood supply to the eye and eyelids from branches of the ECA originates from

▯ The **Facial (external maxillary) artery**

- ***Angular a.*** (terminal branch of Facial a.) anastomose at the medial canthus with the ***dorsonasal a.*** (terminal branch of ophthalmic a.) ⇒ provide blood for the inferior arterial arcades of the eyelids.

▯ The **superficial temporal artery** (smaller of the 2 terminal branch of ECA)

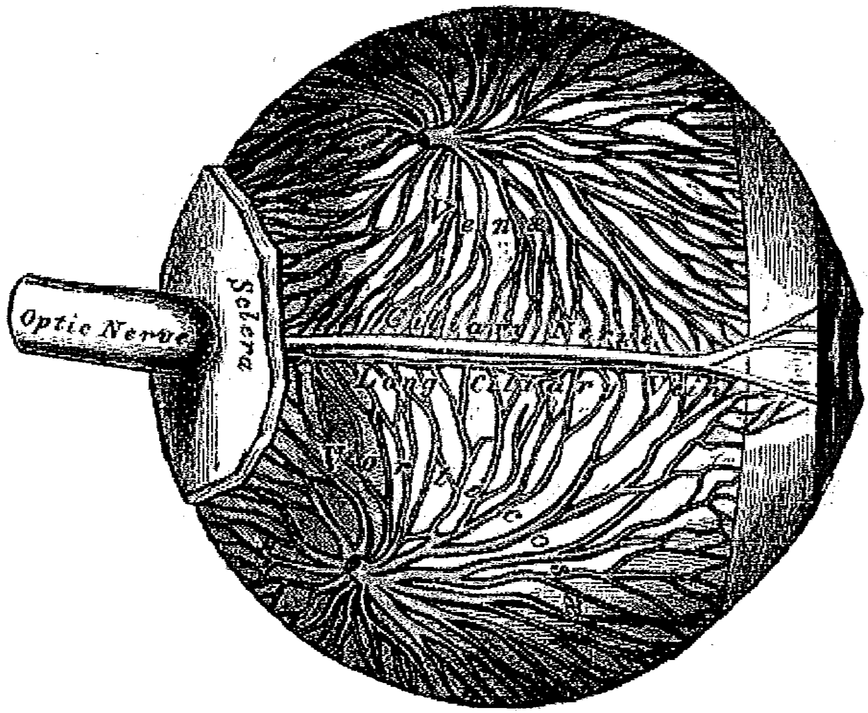
- ***Transverse facial a.*** (the largest branch of the superficial temporal artery) anastomoses with the ***infraorbital a.*** (from maxillary) & ***angular a.***
- The ***zygomatico-orbital a.*** anastomoses with the *lacrimal a.* & its palpebral branches ⇒ participate in the arterial arcade of the eyelids.
- The ***frontal a.*** (termial branch of superficial temporal a.) anastomoses with the ***supraorbital a.*** (Branch of the ophthalmic a.)

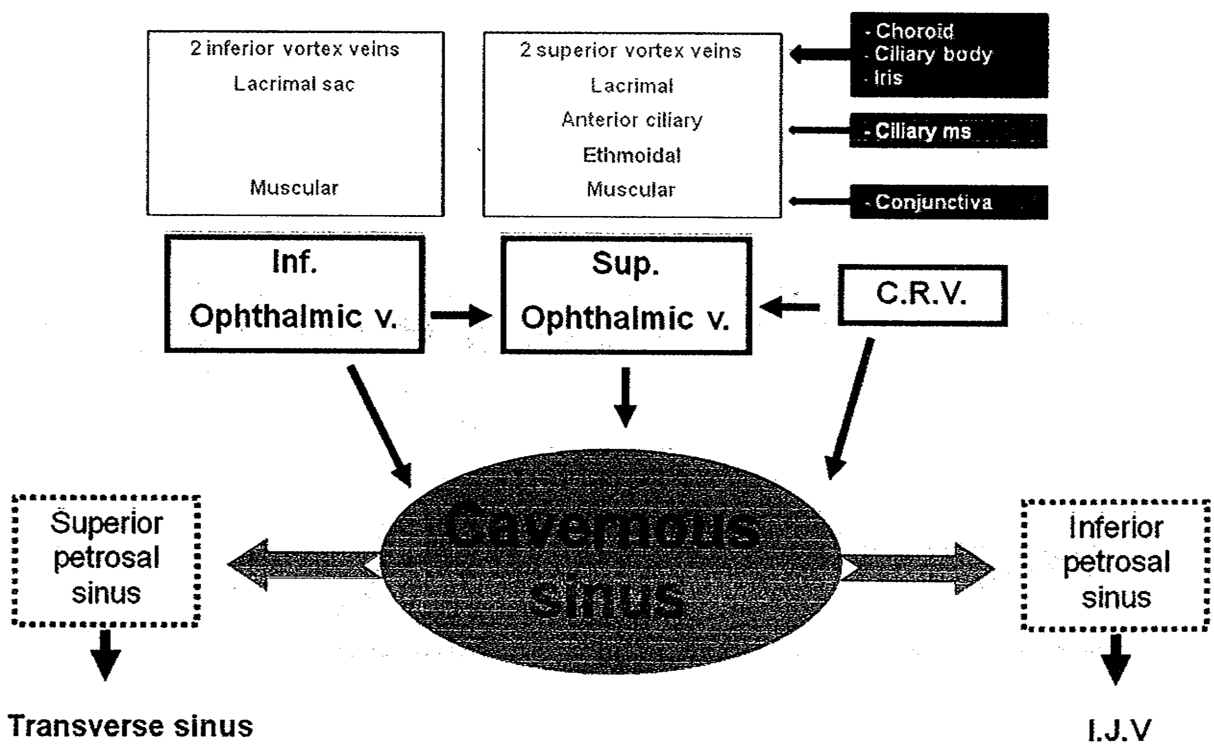
▯ The **internal maxillary artery** (larger of the 2 terminal branches of ECA)

- ***Infraorbital a.*** (originates in the pterygopalatine (sphenomaxillary) fossa) ⇒ IOF (enters the orbit) ⇒ runs in the infraorbital sulcus and canal ⇒ infraorbital foramen (emerge on the face) ⇒ anastomoses with the
  angular a. (of the facial a.)
  transverse facial a. (of the superficial temporal a.) &
  lacrimal a. & dorsonasal a. (of the ophthalmic a.)

- ***Middle meningeal a.*** (branch of maxillary a.) ⇒ anastomoses with the ***Recurrent meningeal a.*** (branch of ophthalmic a.)

N.B. *The recurrent meningeal a. may be large & replace ophthalmic a. or middle meningeal a.*


Optic Nerve
Sclera


2 inferior vortex veins
Lacrimal sac
Muscular
2 superior vortex veins
Lacrimal
Anterior ciliary
Ethmoidal
Muscular
- Choroid
- Ciliary body
- Iris
- Ciliary ms
- Conjunctiva
Inf. Ophthalmic v.
Sup. Ophthalmic v.
C.R.V.
Cavernous sinus
Superior petrosal sinus
Inferior petrosal sinus
Transverse sinus
I.J.V

Veins (valveless)

Venous drainage of the orbit is mainly through the superior & inferior orbital veins. These are markedly tortuous, valveless, and pass through the superior orbital fissure to empty into the cavernous sinus.

Connections:

- The superior ophthalmic v. communicates with the ***angular v.*** which is continuous with the anterior facial vein.
- The inferior ophthalmic v. communicates with the ***pterygoid plexus*** through the I.O.F.

Drainage pathway:

- Two or more ***superior vortex veins*** ⇒ **superior ophthalmic v.** ⇒ ***Cavernous sinus***
- Two or more ***inferior vortex veins*** ⇒ **inferior ophthalmic v.** ⇒ ***Cavernous sinus*** or ***superior ophthalmic v.***
- The ***central retinal v.*** ⇒ ***Cavernous sinus*** or ***superior ophthalmic v.***

Vortex veins:

- Four or more veins that drain the whole uveal tract (limit the posterior extension of choroidal detachment)
- They undergo ampullary dilatation before entering the sclera
- Tributaries
  - Posterior tributaries → Posterior part of ***Choroid*** + ***Optic nerve***
  - Anterior tributaries → Anterior part of the ***choroid*** + ***Ciliary body*** + ***Iris***

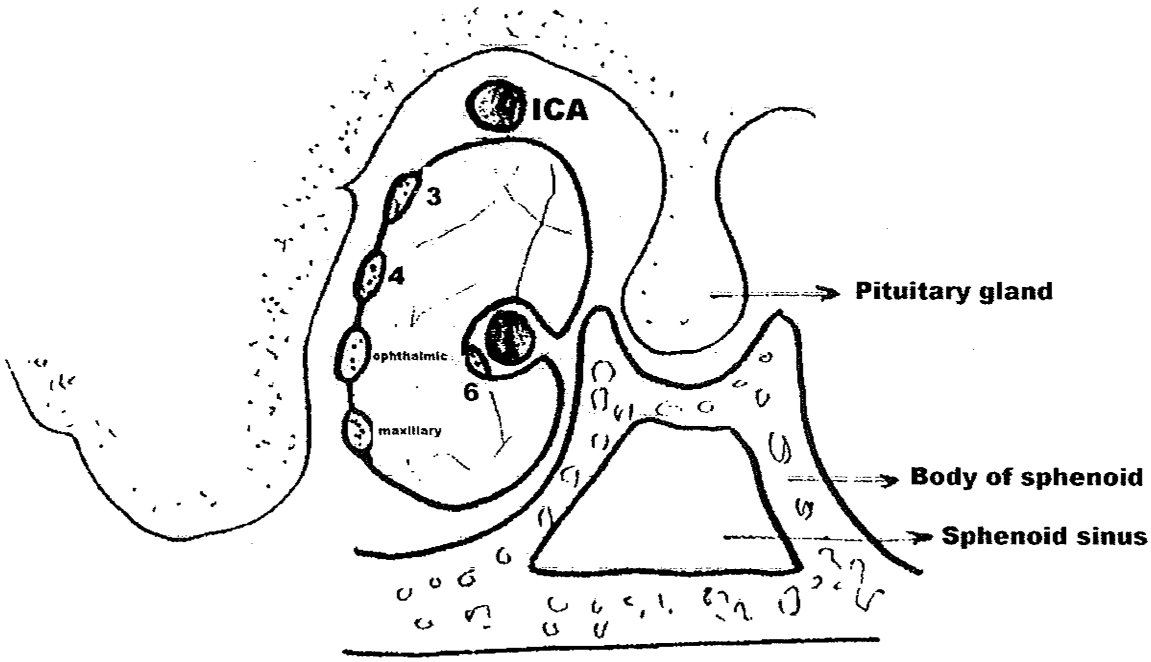
N.B. **veins of the ciliary ms**: ***Most*** → Pass back → choroid → vortex veins
Few → pass anteriorly → pierce the sclera → Ant. Ciliary v.

Superior ophthalmic vein:

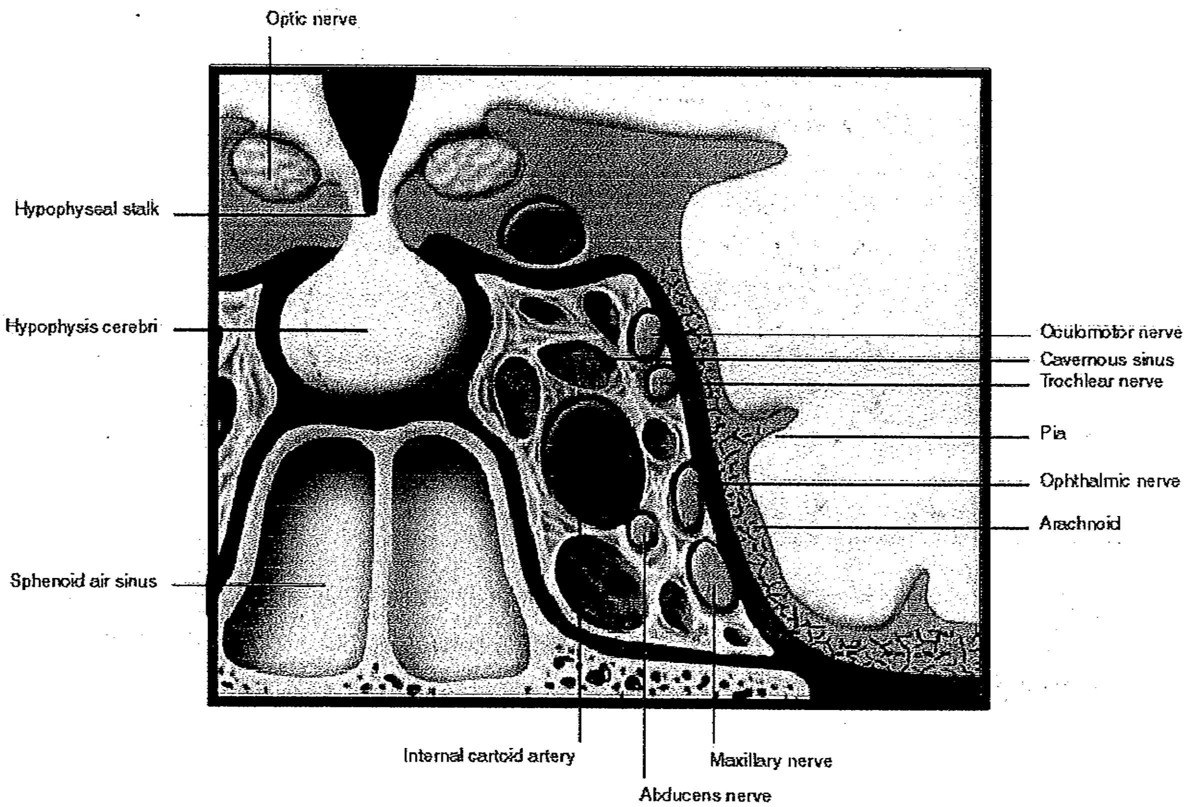
- Starts: (Near the root of the nose) by communication from ***angular v.*** (soon after it has been joined by supraorbital vein)
- Course: Enters the orbit above the M.P.L → Accompany ophthalmic a. → Sup. orbital fissure.
- Drainage → Cavernous sinus.
- Tributaries
  1. **Inferior ophthalmic** vein (usually joins at the superior orbital fissure)
  2. Anterior & Posterior **Ethmoidal** veins
  3. **Lacrimal**
  4. **Muscular**
  5. **Central retinal vein** (usually)
  6. **Anterior ciliary** (drains the ciliary muscles)
  7. Two Superior **vortex** veins.

Inferior ophthalmic vein:

- Starts: (Near the front of the floor of the orbit) as plexus
- Course: Runs on the inferior rectus
- Drainage → Superior ophthalmic vein or Cavernous sinus.
- Tributaries
  1. Two Inferior **vortex** veins
  2. From the **conjunctiva.**
  3. From the **lacrimal** sac
  4. From the lower & lateral ocular **muscles**



ICA
3
4
ophthalmic
6
maxillary
Pituitary gland
Body of sphenoid
Sphenoid sinus



Optic nerve
Hypophyseal stalk
Hypophysis cerebri
Sphenoid air sinus
Oculomotor nerve
Cavernous sinus
Trochlear nerve
Pia
Ophthalmic nerve
Arachnoid
Internal carotid artery
Maxillary nerve
Abducens nerve

Cavernous Sinus

Definition:
An irregular-shaped. endothelium-lined *venous space*.

N.B it is traversed by many septa → cavernous tissue appearance.

Site:

- Between the meningeal and periosteal layers of the dura mater
- On both sides of the body of the ***sphenoid bone***.
- Extends from the medial end of ***superior orbital fissure*** to the apex of ***petrous bone***.

Dimensions:

- Length → **3** cm
- Width → **0.5** cm
- Height → **1** cm

Relations:

- **Anteriorly** → superior orbital fissure. (medial end)
- **Posteriorly** → Cerebral peduncle + Apex of petrous temporal + Trigeminal ganglion.
- **Superiorly** → I.C.A. + Optic nerve & chiasma.
- **Inferiorly** → Body of sphenoid + Sphenoid air sinus.
- **Medially** → Body of sphenoid + sphenoid air sinus + Pituitary gland.
- **Laterally** → Uncus of the brain. (Temporal lobe)
- **Invaginated inside** → I.C.A. + Abducent n. (infero-lateral to the I.C.A.)

> After leaving its canal (at the anterior end of foramen lacerum) → **pierces** the back of the cavernous sinus → **passes** forwards inside the sinus (with the abducent n. inferolateral to it) grooving the side of body of sphenoid → **leaves** the sinus by piercing its roof near the anterior end (bet. 2nd & 3rd cranial nerves)

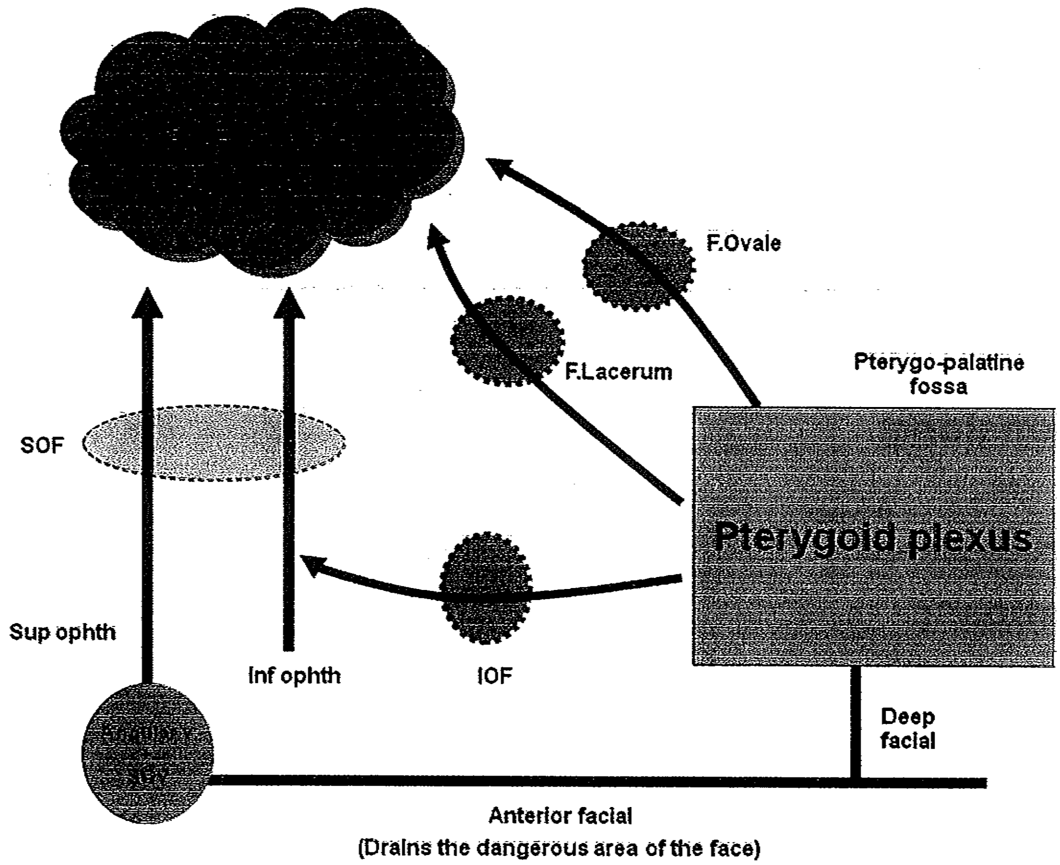
- **Embeded in lateral wall** (from above downwards)
  1) Oculomotor n. → Anteriorly → divides into superior & inferior divisions
  2) Trochlear n. → Anteriorly → crosses to lie superior to oculomotor.
  3) Ophthalmic n. → Anteriorly → divides into frontal, lacrimal & nasociliary.
  4) Maxillary n. → Anteriorly → (no longer present)

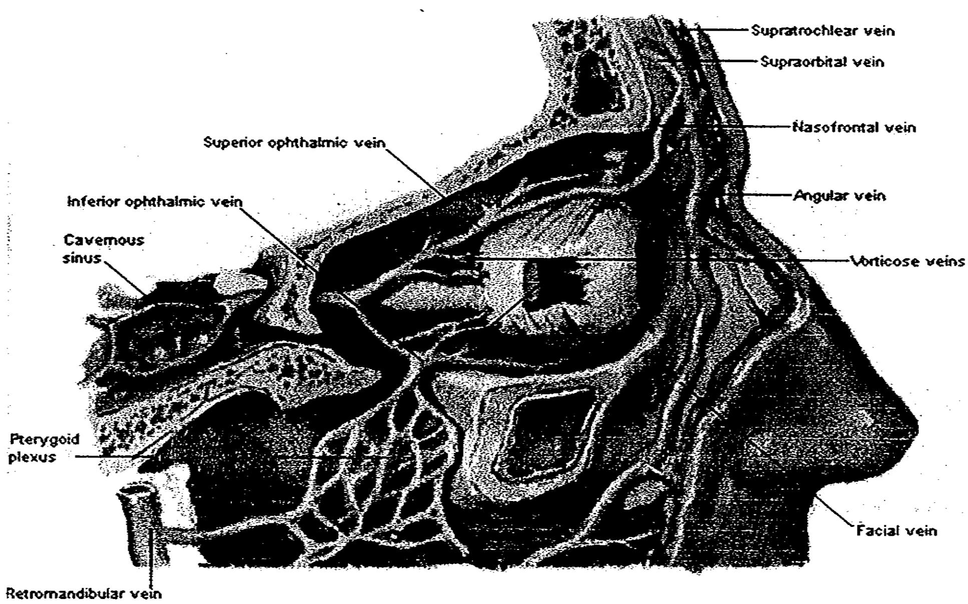
Tributaries:

- Ophthalmic veins + CRV
- Sphenoparietal sinus. ⇒ drains side wall & vault of the skull. (Accompanies M.M.A)
- Superficial middle cerebral v. + Inferior middle cerebral vein.
- Small cerebral veins.
- Hypoglossal veins

Drainage:

- Superior petrosal sinus → Transverse sinus.
- Inferior petrosal sinus → I.J.V.


F.Ovale
F.Lacerum
Pterygo-palatine fossa
SOF
Pterygoid plexus
Sup ophth
Inf ophth
IOF
Deep facial
Anterior facial
(Drains the dangerous area of the face)


Supratrochlear vein
Supraorbital vein
Nasofrontal vein
Superior ophthalmic vein
Angular vein
Inferior ophthalmic vein
Cavernous sinus
Vorticose veins
Pterygoid plexus
Facial vein
Retromandibular vein

Communications:

- Intercavernous sinuses. (usually 3 ⇒ passing through the roof & floor of the pituitary fossa)
- Emissary veins with
  - → pterygoid plexus of veins ⇒ through *foramen ovale* & *foramen lacerum*

Pterygoid plexus →	Communicate with facial vein ⇒ through *deep facial vein*
	Communicate with cavernous sinus ⇒ through .....
	Communicate with inferior ophthalmic v. ⇒ through IOF

  - → pharyngeal plexus of veins ⇒ through *carotid canal*

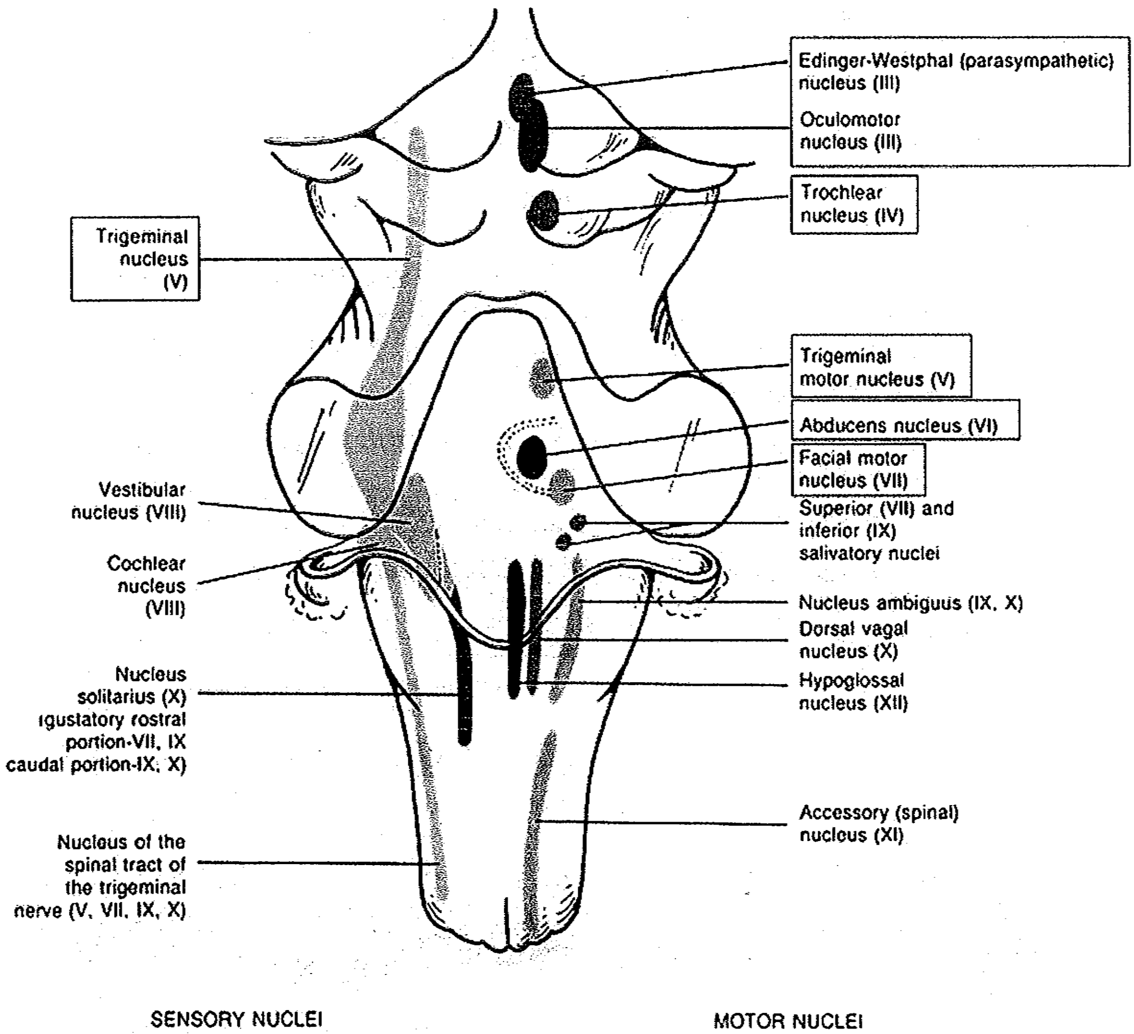
Applied anatomy:

- **Cavernous sinus thrombosis**:
  - May occur due to spread of infection from ***anterior facial vein*** (which drains the dangerous area of the face) through:
    1) Anastomosis between *Angular vein* & *superior ophthalmic* vein at the medial canthus.
    2) Anterior facial vein ⇒ *Deep facial vein* ⇒ pterygoid plexus ⇒ cavernous sinus, through:
       ⇒ Directly : via Emissiary veins
       ⇒ Indirectly: via inferior ophthalmic veins.
  - May occur due to spread of ***labrynthine infection*** through:
    ⇒ Labrynthine vein ⇒ inferior petrosal sinus ⇒ Cavernous sinus.
  - May spread via *superior petrosal sinus* ⇒ ***transverse sinus*** ⇒ *mastoid emissary vein* → swelling behind the ear. (retrograde venous thrombosis)
  - Is usually ***bilateral*** ⇒ because of intercavernous communications.
- Fracture base of the skull → **Carotid cavernous fistula**.

Ocular manifestations of Cavernous sinus thrombosis:

- **Early** ⇒ Ocular pain + Photophobia + Lacrimation
- Features of **venous stasis** ⇒ Proptosis + Chemosis + Lid edema + Papilloedema + retinal venous engorgement
- **Ophthalmoplegia** ⇒ due to involvement of **III, IV, VI** nerves
- **Corneal anethesia** ⇒ due to affection of ophthalmic n.

N.B. In unilateral cases → ***abduent nerve weakness*** is the first indicator of contralateral extension


Edinger-Westphal (parasympathetic) nucleus (III)
Oculomotor nucleus (III)
Trochlear nucleus (IV)
Trigeminal nucleus (V)
Trigeminal motor nucleus (V)
Abducens nucleus (VI)
Facial motor nucleus (VII)
Vestibular nucleus (VIII)
Superior (VII) and inferior (IX) salivatory nuclei
Cochlear nucleus (VIII)
Nucleus ambiguus (IX, X)
Dorsal vagal nucleus (X)
Nucleus solitarius (X) ıgustatory rostral portion-VII, IX caudal portion-IX, X)
Hypoglossal nucleus (XII)
Accessory (spinal) nucleus (XI)
Nucleus of the spinal tract of the trigeminal nerve (V, VII, IX, X)
SENSORY NUCLEI
MOTOR NUCLEI

Nerves of the Eye

Motor nerves

- Oculomotor (N III)
  - Superior division
    - → superior rectus muscle
    - → levator palpebrae superioris muscle.
  - Inferior division
    - → medial rectus
    - → inferior rectus
    - → inferior oblique muscles
    - → motor root to ciliary ganglion (ciliary muscle & sphincter pupillae muscle)
- Trochlear (N IV) → superior oblique muscle
- Abducent (N VI) → lateral rectus muscle

Mixed motor and sensory nerves

- Trigeminal (N V)
  - *Motor* → muscles of mastication
  - *Sensory* from face and eye
  - *Proprioceptive* from muscles of mastication (mesencephalic nucleus and perhaps ocular muscles)
- Facial (N VII)
  - *Motor* → face
  - *Secretory* → submaxillary, sublingual, and lacrimal glands
  - *Taste* from anterior two thirds of tongue

Autonomic nervous system

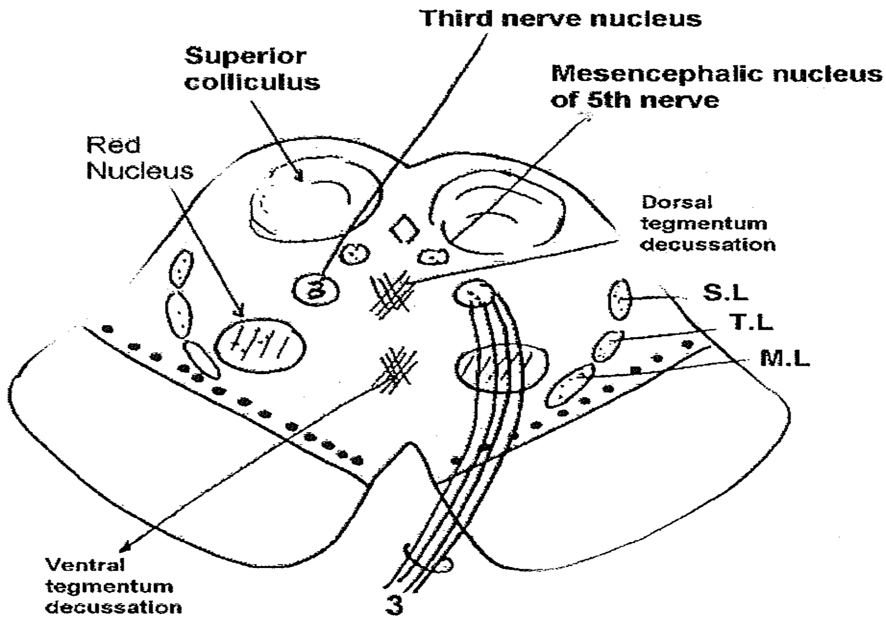
- Parasympathetic
- Sympathetic

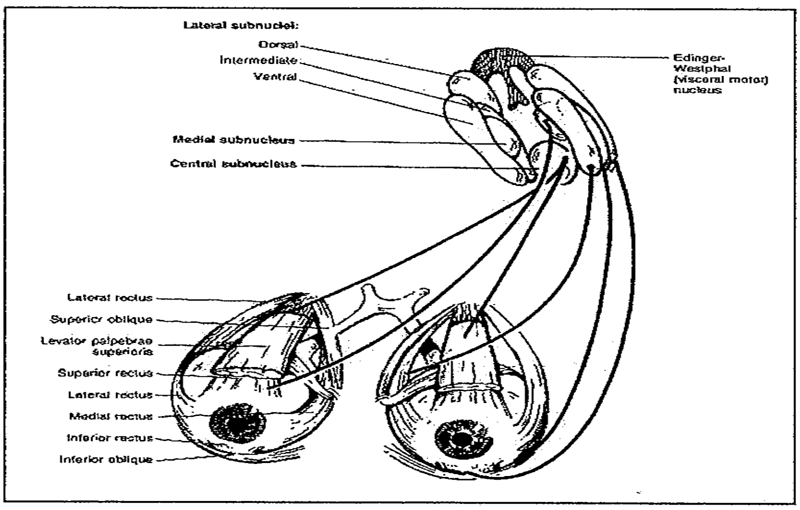
Visual system

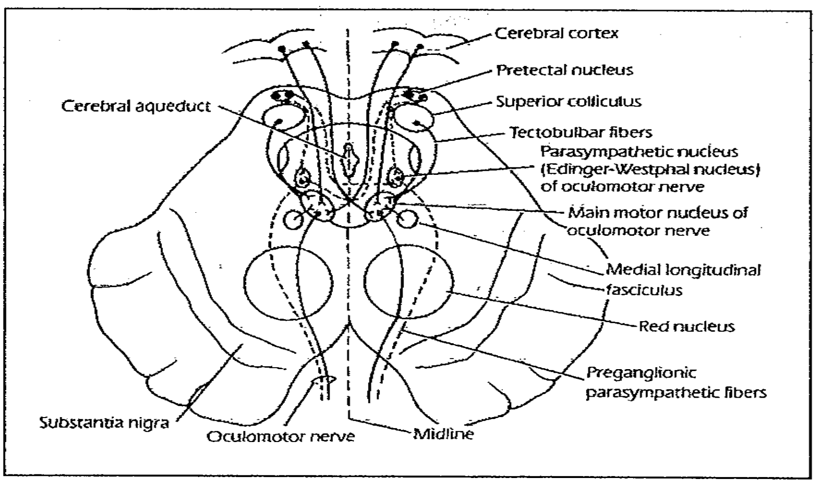
- Optic nerve (N II)
- Optic chiasma
- Optic tract
- Lateral geniculate body
- Optic radiation
- Visual cortex

Cranial Nerves

(1) Olfactory
(2) Optic
(3) Oculomotor
(4) Trochlear
(5) Trigeminal
(6) Abducent
(7) Facial
(8) Vestibulocochlear
(9) Glossopharyngeal
(10) Vagus
(11) Accessory
(12) Hypoglossal


Third nerve nucleus
Superior colliculus
Mesencephalic nucleus of 5th nerve
Red Nucleus
Dorsal tegmentum decussation
S.L
T.L
M.L
Ventral tegmentum decussation
3


Lateral subnuclei:
Dorsal
Intermediate
Ventral
Medial subnucleus
Central subnucleus
Edinger-Westphal (visceral motor) nucleus
Lateral rectus
Superior oblique
Levator palpebrae superioris
Superior rectus
Lateral rectus
Medial rectus
Inferior rectus
Inferior oblique


Cerebral cortex
Pretectal nucleus
Superior colliculus
Cerebral aqueduct
Tectobulbar fibers
Parasympathetic nucleus (Edinger-Westphal nucleus) of oculomotor nerve
Main motor nucleus of oculomotor nerve
Medial longitudinal fasciculus
Red nucleus
Preganglionic parasympathetic fibers
Substantia nigra
Oculomotor nerve
Midline

Oculomotor (3rd cranial) Nerve

Nuclei of origin: (at the upper level of midbrain)

⇒ **Nuclear complex:**

- **Site:** small (5mm) collection of cells located:
  - In the midbrain at the level of the **superior colliculus.**
  - Ventral to the sylvian aqueduct.

  The trochlear nerve nucleus is continuous caudally.

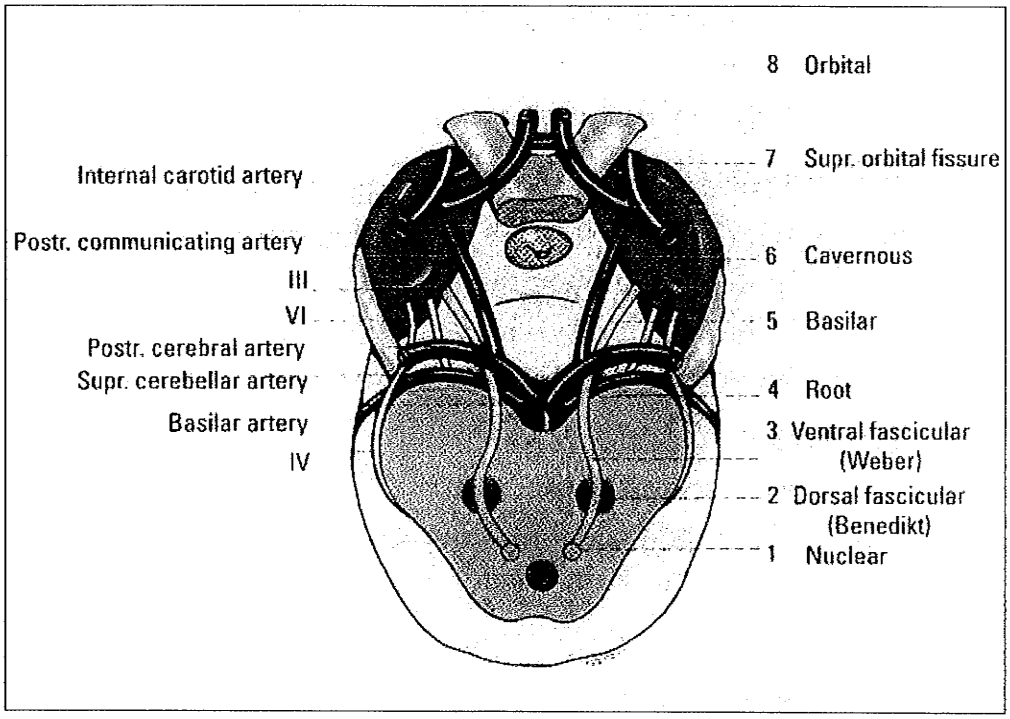
- **Subnuclei:**

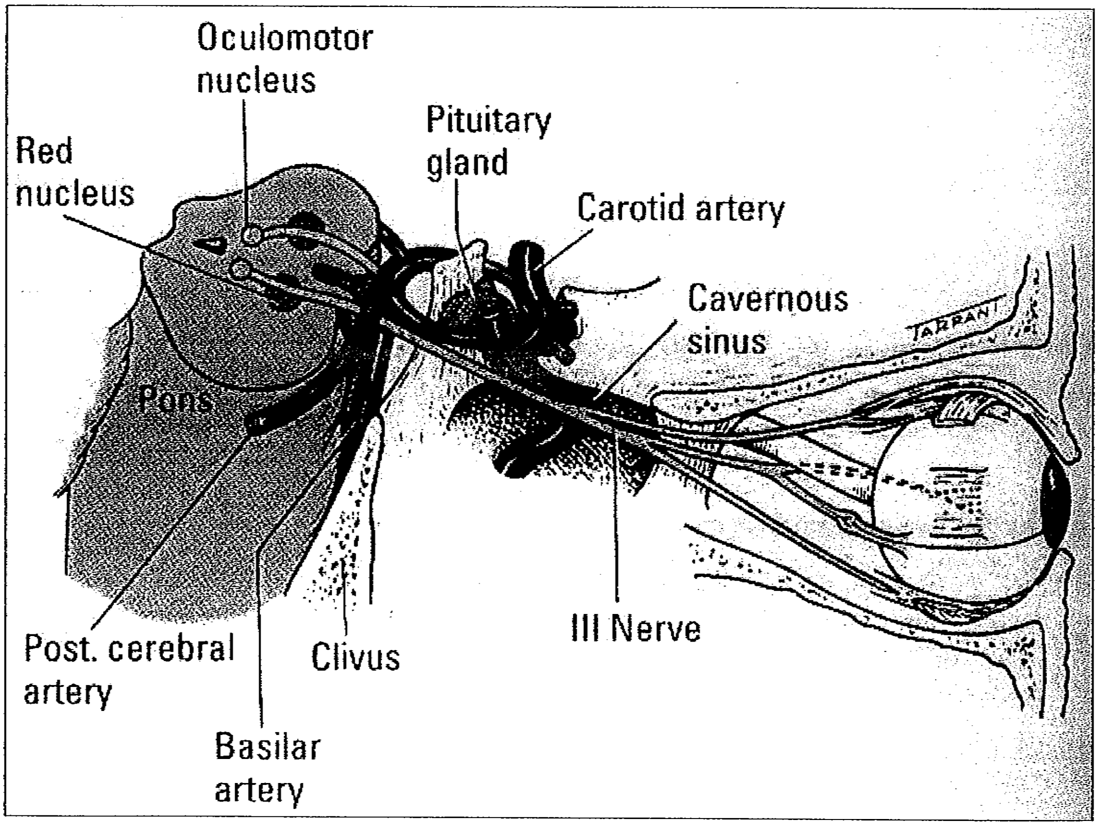
  1) **Levator subnucleus**
     - Unpaired caudal midline structure
     - Innervates both levator muscles.
     - Lesions → bilateral ptosis.
  2) **Superior rectus subnuclei**
     - Paired
     - Innervates the ***contralateral*** superior rectus.
     - Lesion → contralateral superior rectus palsy.
  3) **Medial rectus, inferior rectus & inferior oblique subnuclei**
     - Paired
     - Innervate the ***ipsilateral*** muscles.
     - Lesions of the paired medial rectus subnuclei → wall-eyed bilateral internuclear ophthalmoplegia (WBBINO) → exotropia, defective convergence and adduction.

⇒ **Edinger-Westphal:** (located rostrally and ventrally)
  - Paired.
  - Gives ***preganglionic parasympathetic*** → ciliary ganglion.

Central connections:

- **Nuclear complex** ⇒ Receives fibers from:
  - Both **cerebral hemispheres** (Cortico-nuclear fibers)
  - **Superior colliculus** (Tecto-bulbar fibers) (supplies information from the visual cortex)
  - **Medial longitudinal fasciculus** (connect 3^{rd}, 4^{th}, 6^{th} & 8^{th} cranial nerves)
- **Edinger Westphal nucleus** ⇒ Receives
  - **Corticonuclear** fibers → For near reflex.
  - **Pretectal nucleus** fibers → For light reflex.


8 Orbital
Internal carotid artery
7 Supr. orbital fissure
Postr. communicating artery
6 Cavernous
III
VI
5 Basilar
Postr. cerebral artery
Supr. cerebellar artery
4 Root
Basilar artery
3 Ventral fascicular (Weber)
IV
2 Dorsal fascicular (Benedikt)
1 Nuclear


Oculomotor nucleus
Pituitary gland
Red nucleus
Carotid artery
Cavernous sinus
Pons
Post. cerebral artery
Clivus
III Nerve
Basilar artery

Course and parts:

- **Fasciculus**

- ***Third nerve*** nucleus (*Efferent fibers)* → pass through the ***red nucleus*** → ***substantia nigra*** → emerge at the medial aspect of the ***cerebral peduncle*** → ***interpeduncular fossa.***

- **Lesion:**

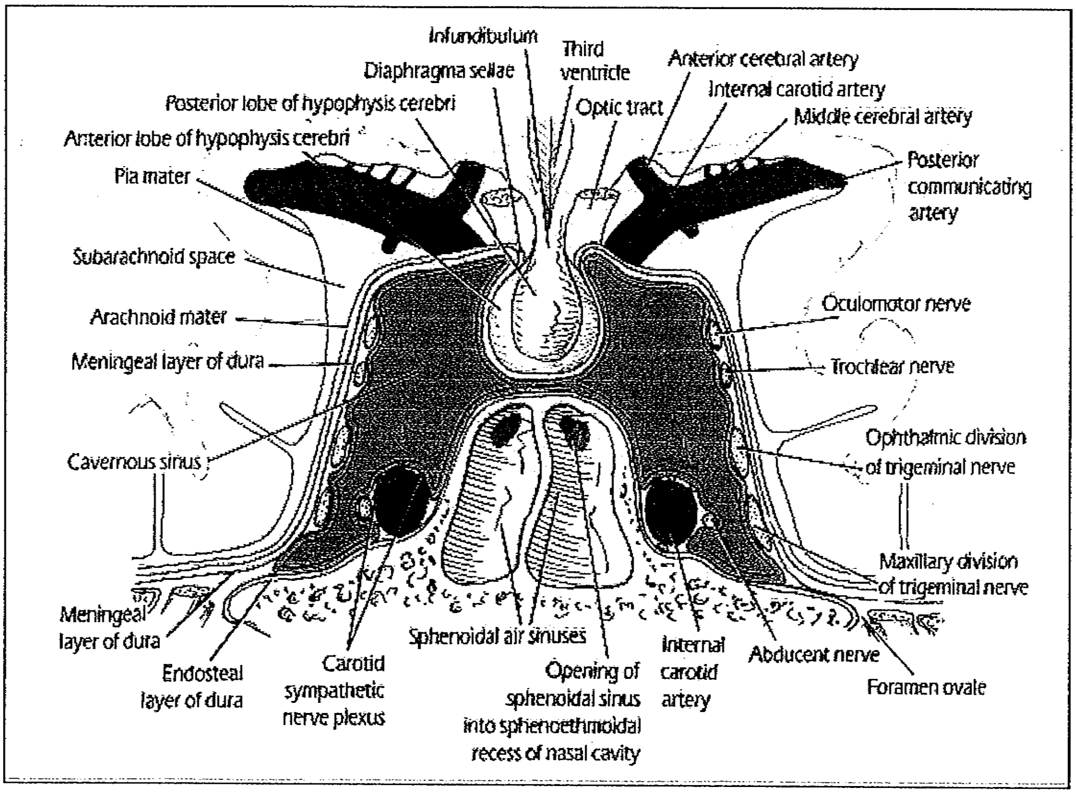
  - At the red nucleus → **Benedikt $**
    ⇒ Ipsilateral 3rd n. palsy & contralateral extrapyramidal signs (ex. hemitremor)
  - At the cerebral peduncle → **Weber $**
    ⇒ Ipsilateral 3rd n. palsy & contralateral hemiparesis.
  - Fasciculus + superior cerebellar peduncle → **Nothnagel $**
    ⇒ Ipsilateral 3rd n. palsy & cerebellar ataxia.
  - **Benedikt $** + **Nothnagel $** → **Claude $**
  - **Parinaud's $** = **Sylvian aqueduct $** = **Dorsal midbrain lesion**
    ⇒ Bilateral efferent pupillary defect + vertical gaze palsy

- **Basilar part** (commonest site of isolated 3rd n. lesion)

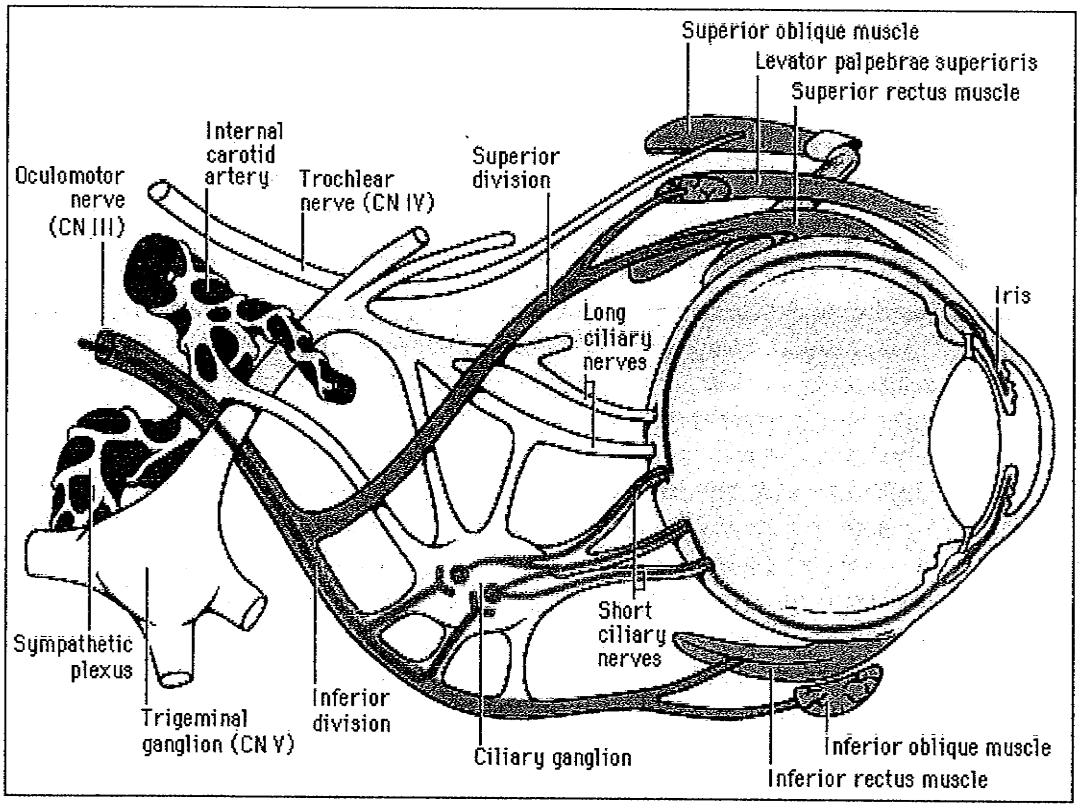
- Starts as a series of 'rootlets' which leave the midbrain on the medial aspect of the cerebral pecduncle → coalesce to form the main trunk
  → Passes between ***posterior cerebral a.*** (above) & ***superior cerebellar a.*** (below)
  → Running lateral to and parallel with the ***posterior communicating a.***

- **Lesion → Isolated 3rd n. palsy**

  - As the nerve traverses the base of the skull along its subarachnoid Course unaccompanied by any other cranial nerve, isolated 3rd n. palsies are commonly basilar. By **Aneurysm** of the posterior communicating a. or **subdural or extradural hematoma**
  - The pupillomotor parasympathetic fibers are located superficially in the superomedial part of the 3rd n. They get blood supply from **pial blood vessels**, while the main trunk of 3rd n. is supplied by **vasa nervorum**.
    1. Surgical lesions such as aneurysms, trauma & uncal herniation → involve the pupil by compressing the pial blood vessels & the superficially located pupillary fibres.
    2. Medical lesions as hypertension & diabetes → usually spare the pupil. This is because the microangiopathy associated with medical lesions involves the vasa nervorum causing ischemia of the main trunk of the nerve, sparing the superficiallly located pupillary fibers.)



Infundibulum
Third ventricle
Diaphragma sellae
Anterior cerebral artery
Internal carotid artery
Posterior lobe of hypophysis cerebri
Optic tract
Middle cerebral artery
Anterior lobe of hypophysis cerebri
Pia mater
Posterior communicating artery
Subarachnoid space
Oculomotor nerve
Arachnoid mater
Meningeal layer of dura
Trochlear nerve
Cavernous sinus
Ophthalmic division of trigeminal nerve
Maxillary division of trigeminal nerve
Meningeal layer of dura
Endosteal layer of dura
Carotid sympathetic nerve plexus
Sphenoidal air sinuses
Opening of sphenoidal sinus into sphenoethmoidal recess of nasal cavity
Internal carotid artery
Abducent nerve
Foramen ovale



Superior oblique muscle
Levator palpebrae superioris
Superior rectus muscle
Internal carotid artery
Oculomotor nerve (CN III)
Trochlear nerve (CN IV)
Superior division
Iris
Long ciliary nerves
Short ciliary nerves
Sympathetic plexus
Trigeminal ganglion (CN V)
Inferior division
Ciliary ganglion
Inferior oblique muscle
Inferior rectus muscle

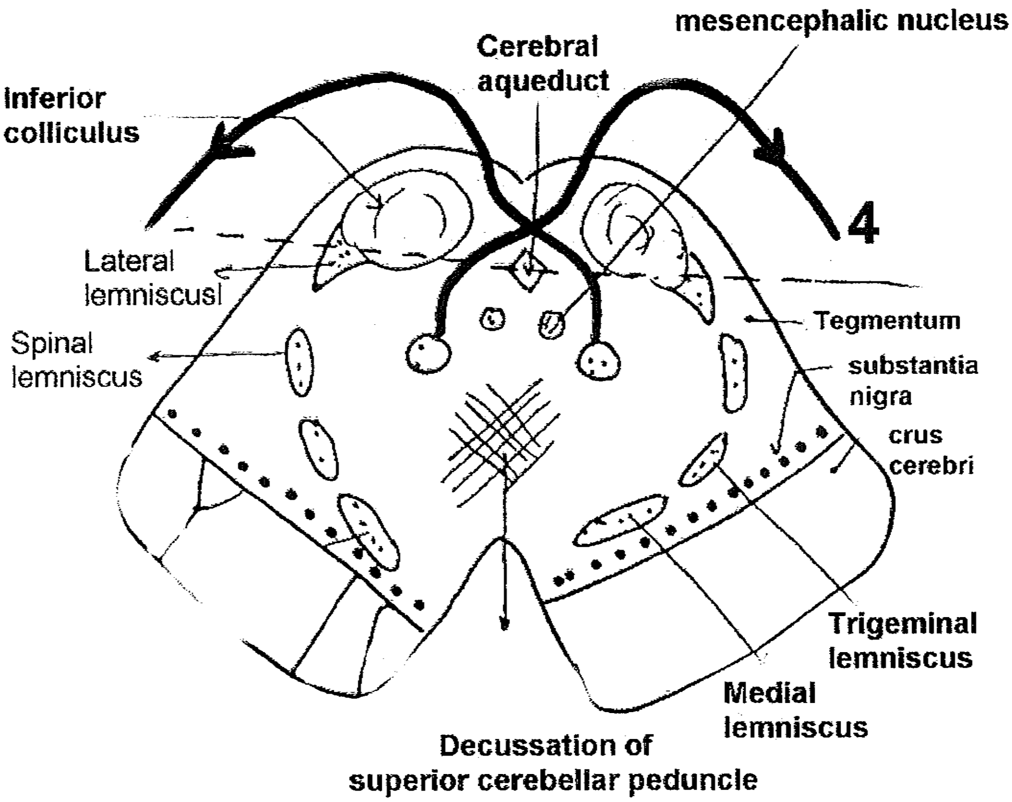
- **Intracavernous part**

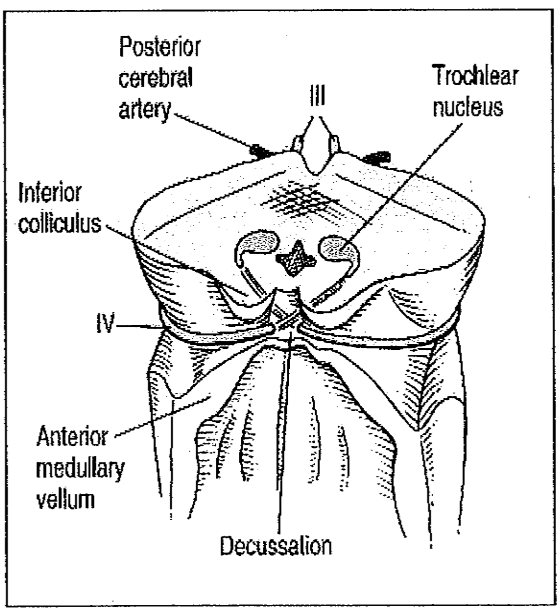
  - **Third nerve**
    → Enters the cavernous sinus by piercing the dura about midway between the anterior and posterior clinoid processes
    → Runs in the lateral wall (where it receives sympathetic fibers from plexus around I.C.A.) above the 4th nerve
    → Divides in the anterior part of the cavernous sinus into superior (smaller) and inferior (larger) branches which enter the orbit through the superior orbital fissure within the annulus of Zinn.

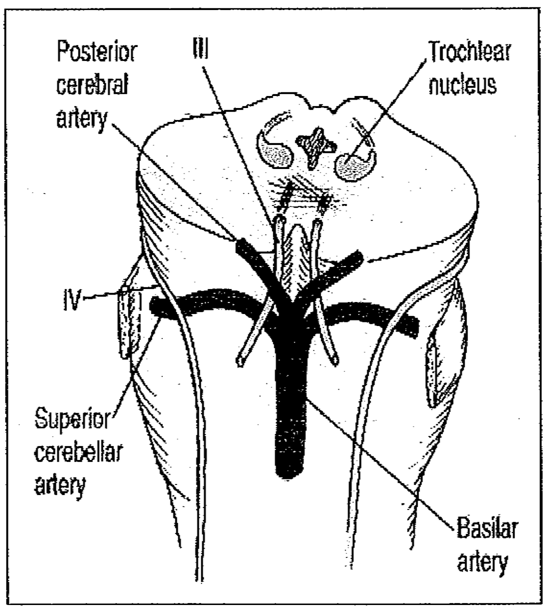
  - **Lesion → 3rd n. palsies**
    Usually associated with 4th & 6th nerves and the First division of the 5th nerve

- **Intraorbital part**

  - **Superior division** → ***Levator Palpebrae superiosis + Superior rectus.***
  - **Inferior division** → ***Medial rectus + Inferior rectus + Inferior oblique.***
  - **Parasympathetic preganglionic fibers** → pass with *n. to inf. oblique* → ***Ciliary ganglion*** (relay) → ***Postganglionic*** parasympathetic → ***short ciliary*** nerves → constrictor pupillae muscle + ciliary muscle.
  - **Sympathetic postganglionic fibers** → pass with n. to *levator palpebrae superiosis* → ***Muller muscle.***


mesencephalic nucleus
Cerebral aqueduct
Inferior colliculus
4
Lateral lemniscusl
Spinal lemniscus
Tegmentum
substantia nigra
crus cerebri
Trigeminal lemniscus
Medial lemniscus
Decussation of superior cerebellar peduncle


Posterior cerebral artery
III
Trochlear nucleus
Inferior colliculus
IV
Anterior medullary vellum
Decussation


Posterior cerebral artery
III
Trochlear nucleus
IV
Superior cerebellar artery
Basilar artery

Trochlear (4th cranial) Nerve

Nucleus: small group of cells located:

- In the midbrain at the level of the **inferior colliculus.**
- Ventral to the sylvian aqueduct (near its connection with the 4th ventricle)
- It is caudal to, and continuous with, the 3rd nerve nuclear complex.

Central connections are the same as main 3rd nerve nucleus (nuclear complex)

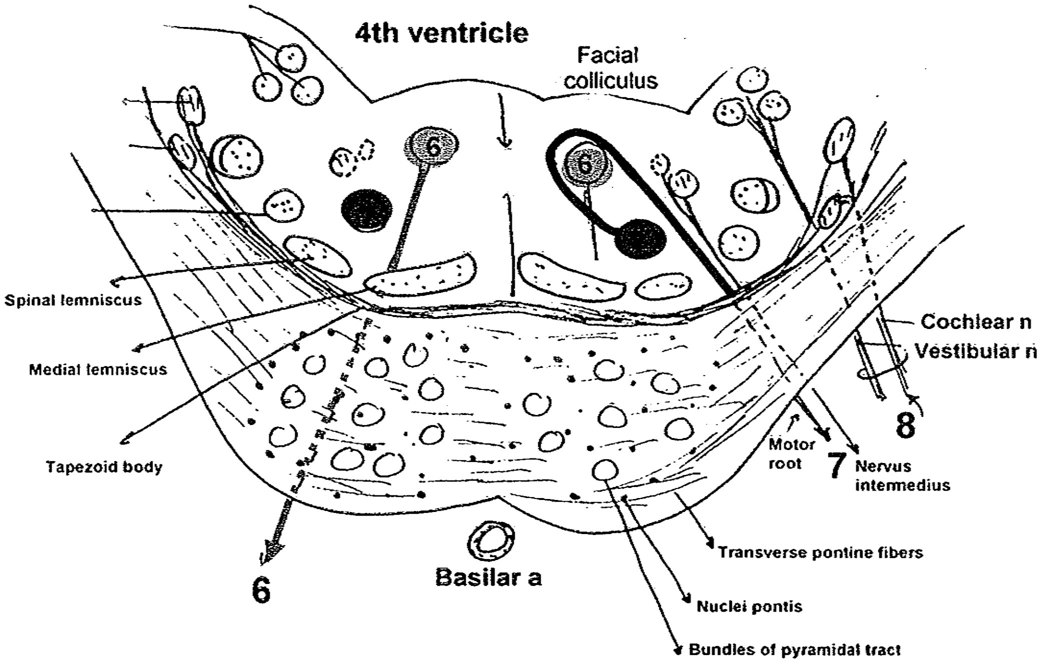
Course and parts:

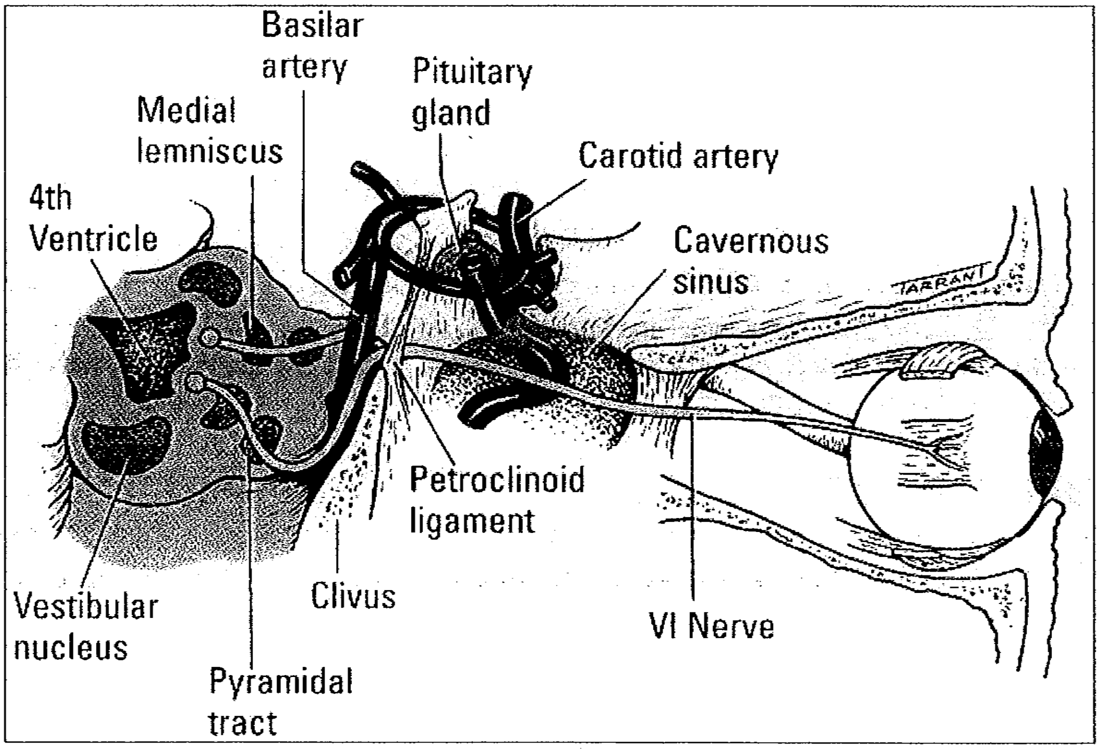
- **Fasciculus**
  - Consists of axons which curve posteriorly & decussate around the cerebral aqueduct in the ***anterior medullary velum.***
- **The trunk**
  - It leaves the brain stem on the dorsal surface just caudal to the inferior colliculus → curves laterally around the brain stem → runs forwards beneath the free edge of the tentorium → passes between the ***posterior cerebral artery*** & the ***superior cerebellar artery***
- **Intracavernous part**
  - 4th nerve
    - → Enters the cavernous sinus by piercing the dura at about the level of the posterior clinoid process (posterior to the entrance of the oculomotor nerve)
    - → Runs in the lateral wall inferior to the third nerve and above the first division of the fifth
    - → In the anterior part of the cavernous sinus it rises and passes through the superior orbital fissure above and lateral to the annulus of Zinn.
- **Intraorbital part** → superior oblique muscle.
  - It passes anteriorly and medially, crossing above the ***oculomotor nerve***, the ***levator palpebrae superioris*** muscle, and the ***superior rectus*** muscle. It enters the superior oblique muscle on its ***orbital surface.***

Important features of the fourth (trochlear) nerve

- It is the only cranial nerve to emerge from the ***dorsal aspect*** of the brain.
- It is a ***crossed*** cranial nerve; this means that the fourth nerve nucleus innervates the contralateral superior oblique muscle.
- It is a very ***long & slender*** nerve & it is the ***smallest*** cranial n.
- The trochlear nucleus cells are connected by the ***medial longitudinal*** fasciculus to the *oculomotor* nucleus (but not the abducent nucleus), the *vestibular* nuclei, and the *trigeminal* sensory nucleus.

Lower level of pons





Abducent (6th cranial) Nerve

Nucleus:

- Site:
  - At the middle (lower) level of the pons.
  - Ventral to the floor of the 4th ventricle (closely related to the horizontal gaze centre.)
  - The fasciculus of the 7th nerve curves around the abducent nucleus and produces an elevation in the floor of the 4th ventricle (facial colliculus).
- Lesion → Ipsilateral 6th nerve palsy + Ipsilateral LMN 7th nerve palsy.

Central connections are the same as main 3rd nerve nucleus (nuclear complex)

Course and parts:

- **Fasciculus**
  - Passes ventrally to leave the brain stem at the ponto-medullary junction, just lateral to the pyramidal prominence. (In a deep groove between the lower border of pons anteriorly and the pyramid of the medulla posteriorly.)
  - **Lesion :**
    - As it passes through the PPRF → **Foville syndrome**
      ⇒ Ipsilateral 5th 6th 7th 8th nerves palsies + central sympathetic fibres.
    - As it passes through the Δ tract → **Millard-Gubler** syndrome
      ⇒ Ipsilateral 6th n. palsy + contralateral hemiplegia.

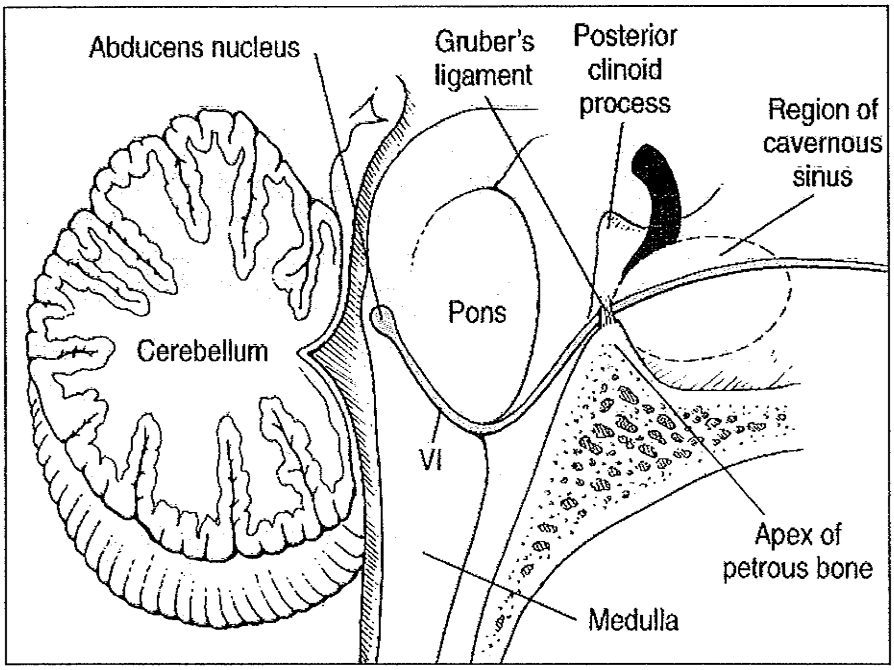
- **Basilar part**
  - Leaves the brain stem at the ponto-medullary junction
    → Passes upwards close to the base of' the skull
    → Crossed by the ***anterior inferior cerebellar artery*** (1st branch of basilar a.)
    → Pierces the dura below the posterior clinoids
    → Crosses the ***apex of petrous*** deep to the ***petrosphenoidal lig.***
    → Enters the cavernous sinus.

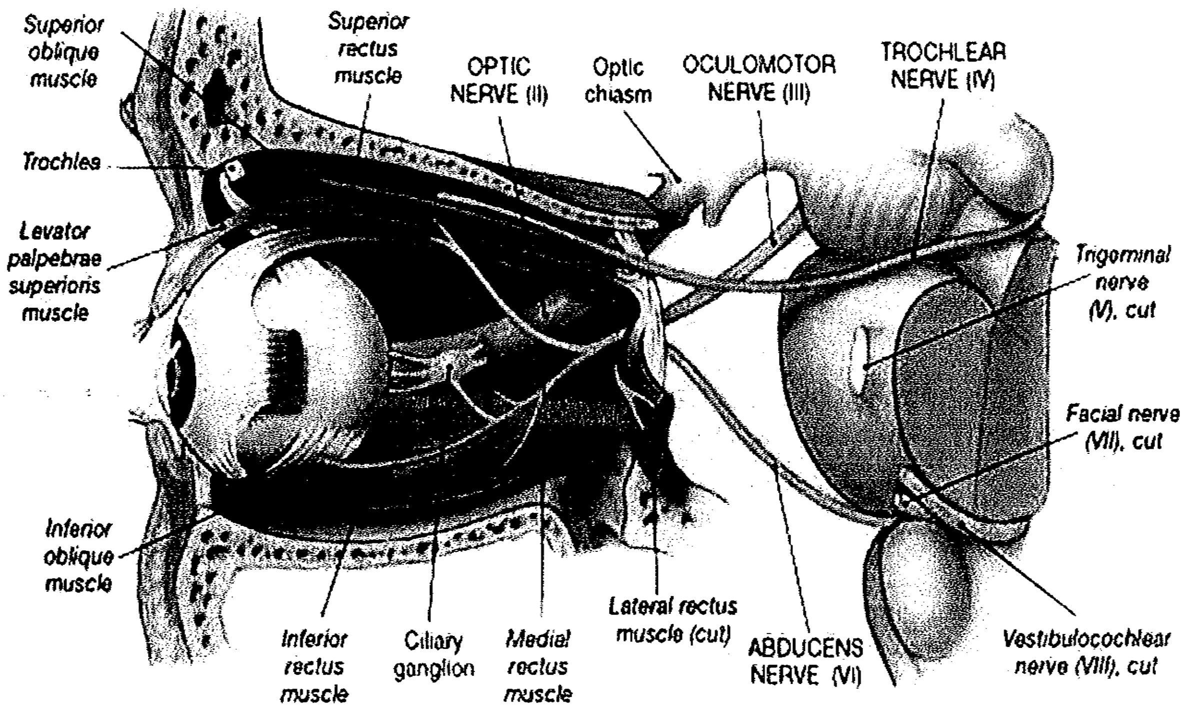
    N.B **Petrosphenoidal ligament** is stretched between the posterior clinoid process & apex of temporal bone → The ***trigeminal n.*** passes above it while ***abducent n.*** passes below it

  - **Causes of lesion in this part:**
    - Acoustic neuroma. • Nasopharyngeal tumours • Raised intracranial pressure
    - Basal skull fracture • Gradenigo $ (most frequently caused by mastoiditis or acute petrositis)

- **Intracavernous part**
  - Runs forwards inferolateral to the I.C.A. at lower level than the **3rd** & **4th** nerves, as well as the ophthalmic n.
  - **Lesion → 6th n. palsy + postganglionic Horner $** (Parkinson sign)

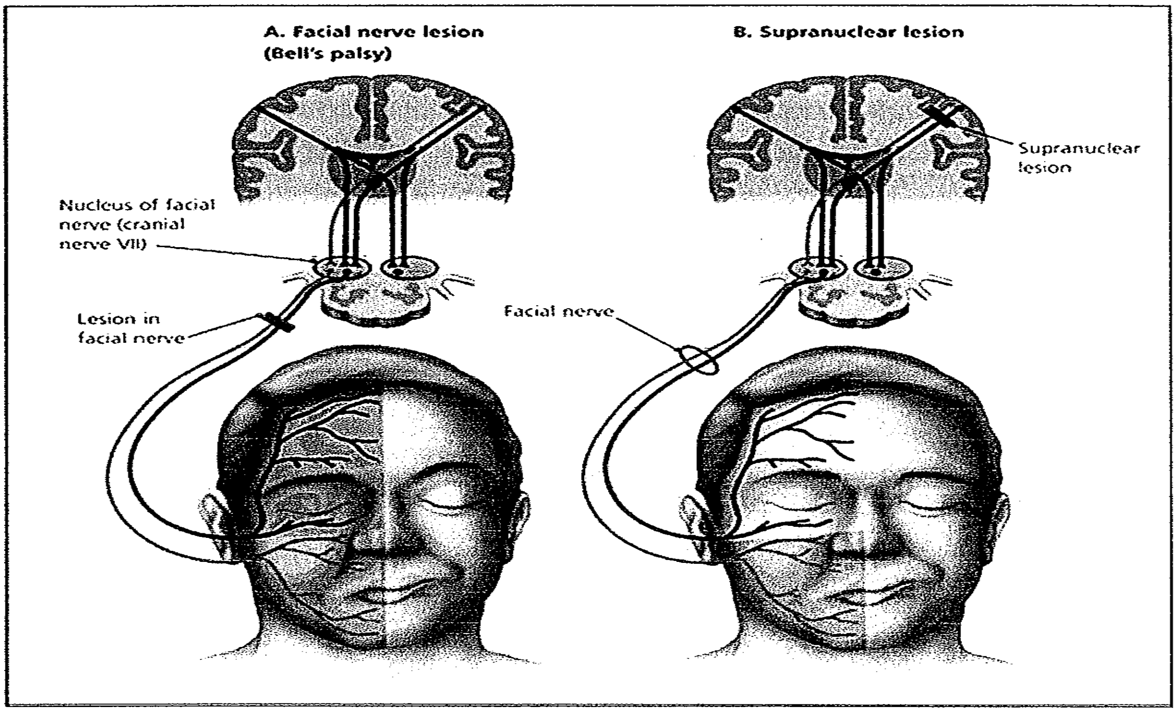
- **Intraorbital part** → Superior orbital fissure within the annulus of Zinn (between the two heads of the lateral rectus muscle) → ***lateral rectus muscle***. (Through its bulbar surface).


Abducens nucleus
Gruber's ligament
Posterior clinoid process
Region of cavernous sinus
Cerebellum
Pons
VI
Apex of petrous bone
Medulla

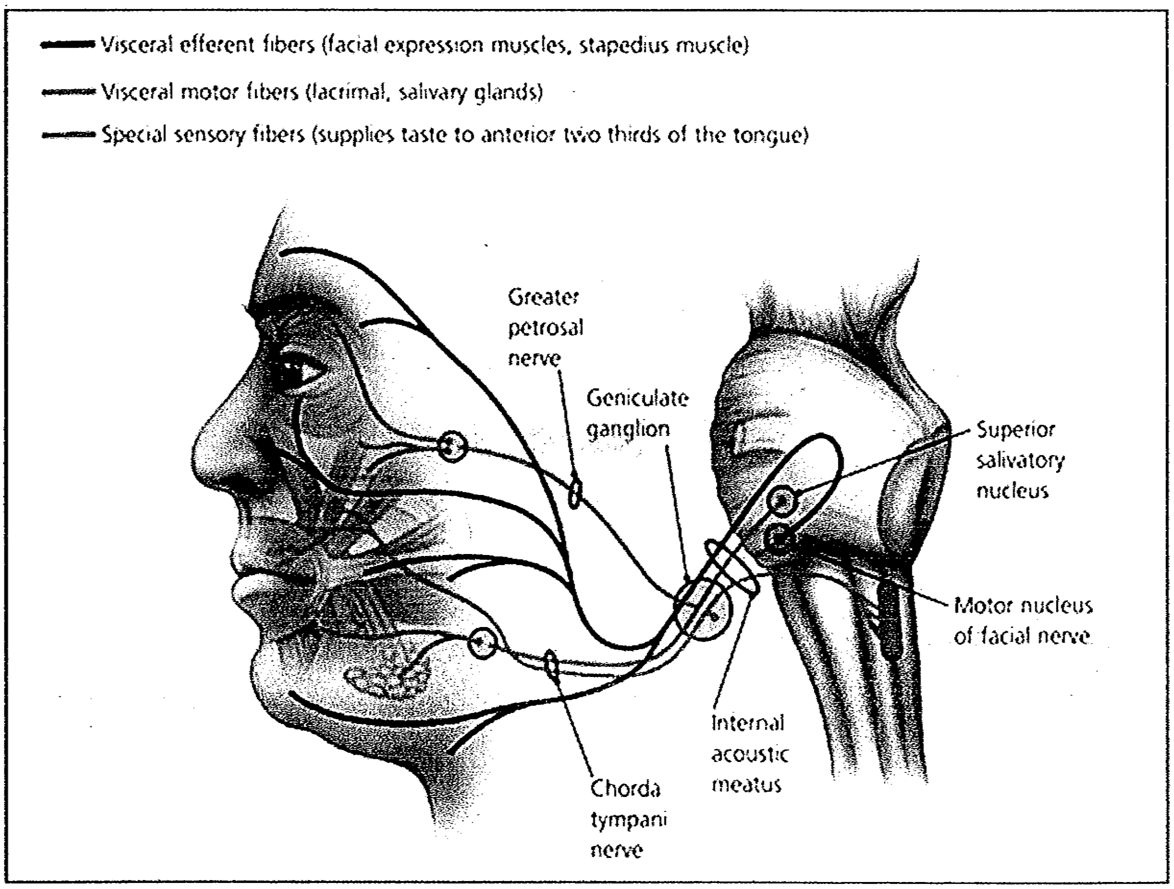

Superior oblique muscle
Superior rectus muscle
OPTIC NERVE (II)
Optic chiasm
OCULOMOTOR NERVE (III)
TROCHLEAR NERVE (IV)
Trochlea
Levator palpebrae superioris muscle
Trigeminal nerve (V), cut
Facial nerve (VII), cut
Inferior oblique muscle
Inferior rectus muscle
Ciliary ganglion
Medial rectus muscle
Lateral rectus muscle (cut)
ABDUCENS NERVE (VI)
Vestibulocochlear nerve (VIII), cut

Important features of the 6th (abducent) nerve

- It has the longest intracranial course of any of the motor nerves of the eye. It makes a sharp turn over the petrous ridge, which makes it vulnerable to ***trauma*** & ***increased intracranial pressure.***
- Destroying a ***nucleus*** impairs not only abduction of the lateral rectus muscle on the same side but also impairs adduction of the medial rectus muscle on the opposite side because each nucleus contains neurons whose axons cross the midline and ascend in the medial longitudinal fasciculus to the medial rectus muscle motor cells in the oculomotor nuclear complex.
- Destruction of an abducent ***nerve root*** impairs only the lateral rectus muscle on the same side.
- An isolated sixth nerve palsy is therefore never nuclear in origin (very close to the nuclei)



A. Facial nerve lesion
(Bell's palsy)
B. Supranuclear lesion
Supranuclear
lesion
Nucleus of facial
nerve (cranial
nerve VII)
Lesion in
facial nerve
Facial nerve



Visceral efferent fibers (facial expression muscles, stapedius muscle)
Visceral motor fibers (lacrimal, salivary glands)
Special sensory fibers (supplies taste to anterior two thirds of the tongue)
Greater
petrosal
nerve
Geniculate
ganglion
Superior
salivatory
nucleus
Motor nucleus
of facial nerve
Internal
acoustic
meatus
Chorda
tympani
nerve

Facial (7^{th} cranial) Nerve

Mixed nerve = motor + sensory + parasympathetic (greater petrosal n. & chorda tympani)

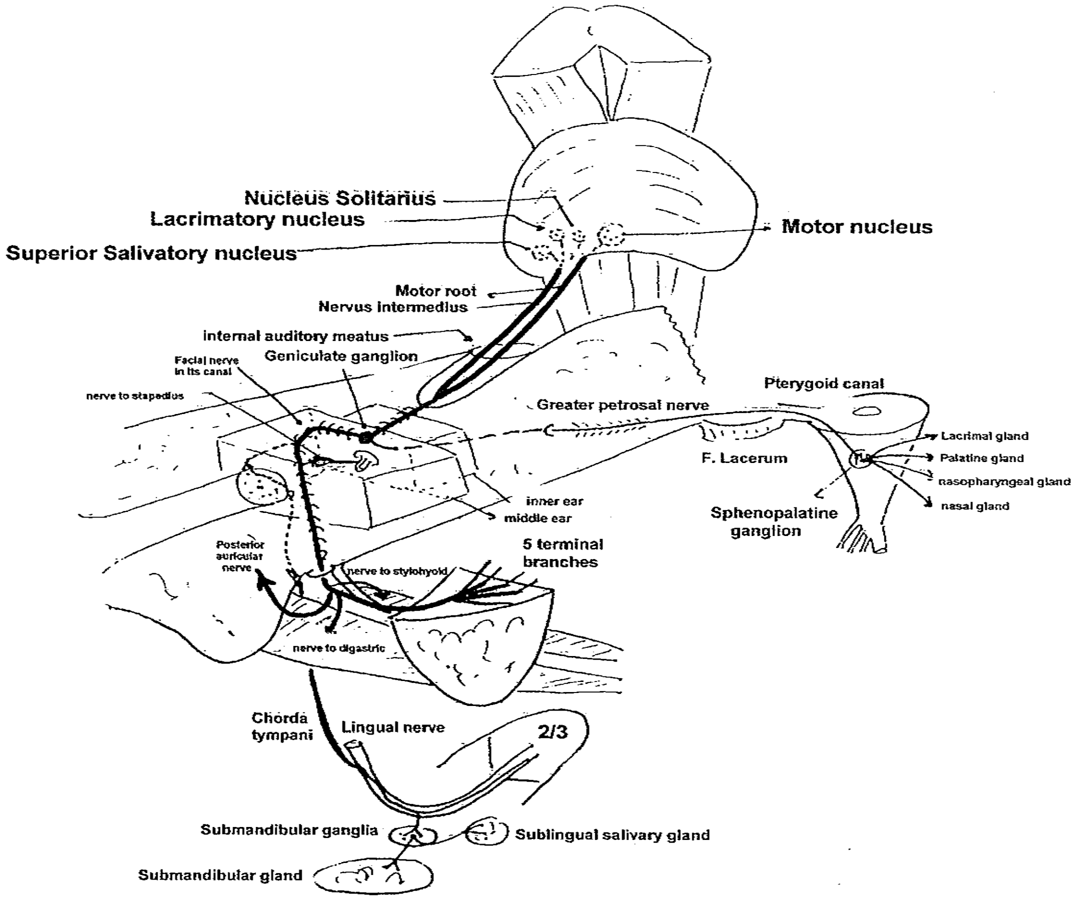
Nuclei of origin:

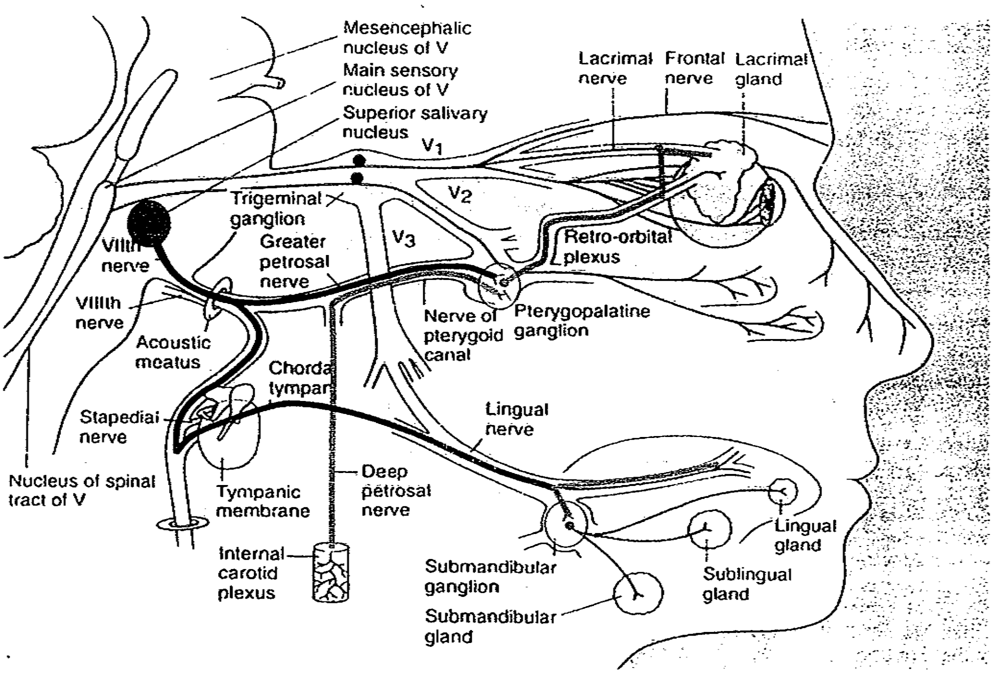
- **Facial Motor nucleus:**
  - Located in the ***lower pons*** (medial to the spinal trigeminal tract & lateral to the fibers of the abducent n.)
  - Supplies → ***2^{nd} branchial arch***.
  - The upper part (which project to muscles of upper part of the face) receives impulses from cortico-nuclear tracts of both sides, the lower part (which project to muscles of lower part of the face) receives impulses from contralateral cortico-nuclear tract only
    ⇒ So unilateral UMNL (supranuclear) → contralateral affection of lower facial muscles only
- **Nucleus solitarius:** (Its upper part) (gustatory or taste nuclei)
  - located in the ***medulla***.
  - Receives taste from ***anterior 2/3 of tongue*** + soft palate + floor of mouth.
  - Pathway :
    → Afferent: **bipolar cells of geniculate ganglion** (brings taste sensation)
      - Peripheral axons → brings taste from anterior 2/3 of tongue + soft palate + floor of mouth.
      - Central axons → synapse in nucleus solitarius.

    → Efferent: **Cells of nucleus solitarius** (sends taste sensation) to contralateral cerebral cortex.
- **Parasympathetic nuclei:**
  - **Lacrimatory nucleus** → Parasympathetic preganglionic fibers to **sphenopalatine ganglion** ⇒ ***lacrimal*** gland
    ⇒ It receives afferent fibers from *hypothalamus* (for emotional response) & from the *sensory nuclei of the trigeminal nerve* (for reflex lacrimation to irritation of the cornea or conjunctiva.)
  - **Superior salivatory nucleus** → Parasympathetic preganglionic fibers to **submandibular ganglion** ⇒ ***sublingual*** & ***submandibular***, palatine, nasal & nasopharyngeal glands.

Course:

- ***In the brain stem***
  - It has 2 roots:
    → ***Motor root*** (large, medial) → pass medially and posteriorly to the floor of the fourth ventricle to rotate around each abducent nucleus.
    → ***Nervus intermedius of Wrisberg*** (small, lateral) attached to the rest of nuclei.
  - Both roots emerge from the anterior surface of the brain stem at the inferior border of the pons, lateral to the abducent nerve.
- ***Intracranial & extracranial course***
  - On emerging from the brain stem → Pass laterally in the posterior cranial fossa → accompanies the vestibulo-cochlear nerve to the ***internal auditory meatus*** → Facial canal.
  - In the FACIAL CANAL:
    → Runs laterally above the inner ear
    → Makes a sharp backward bend to run in the upper part of medial wall of middle ear (at the region of the sharp bend it represents the geniculate ganglion.)
    → Descends behind the middle ear → Stylomastoid foramen (emerge from the skull).
  - Below the STYLOMASTOID FORAMEN:
    → The nerve turns anteriorly around the base of the styloid process to enter the parotid gland, where it divides into its terminal divisions.


Nucleus Solitarius
Lacrimatory nucleus
Superior Salivatory nucleus
Motor nucleus
Motor root
Nervus intermedius
Internal auditory meatus
Geniculate ganglion
Pterygoid canal
Greater petrosal nerve
Lacrimal gland
Palatine gland
nasopharyngeal gland
nasal gland
F. Lacerum
Sphenopalatine ganglion
inner ear
middle ear
5 terminal branches
nerve to stylohyoid
nerve to digastric
Chorda tympani
Lingual nerve
2/3
Submandibular ganglia
Sublingual salivary gland
Submandibular gland


Mesencephalic nucleus of V
Main sensory nucleus of V
Superior salivary nucleus
V_1
V_2
V_3
Lacrimal nerve
Frontal nerve
Lacrimal gland
Trigeminal ganglion
Greater petrosal nerve
Retro-orbital plexus
VIIth nerve
VIIIth nerve
Acoustic meatus
Nerve of pterygoid canal
Pterygopalatine ganglion
Chorda tympani
Stapedial nerve
Lingual nerve
Nucleus of spinal tract of V
Tympanic membrane
Deep petrosal nerve
Lingual gland
Internal carotid plexus
Submandibular ganglion
Sublingual gland
Submandibular gland

Branches:

- **In the Facial canal:**

  - ***Greater Petrosal nerve:***
    - From ***Geniculate Ganglion***
    - leaves the petrous bone (hiatus carrying its name)
    - pass forwards on petrous bone (groove carying its name)
    - Pterygoid canal (in the anterior wall of foramen lacerum)
      where it unites with deep petrosal n. to form ***Vidian nerve*** (nerve of pterygoid canal)
    - ***Pterygopalatine fossa***
    - ***Sphenopalatine ganglion*** (relay) → postganglionic parasympathetic fibers → Join ***maxilary n.*** (of trigeminal) → ***Zygomatico-temporal*** branch → ***Lacrimal n.*** (of ophthalmic) → **Lacrimal Gland.**

  - ***Nerve to Stapedius.***

  - ***Chorda Tympani:***

    ⇒ Course:
    → Arise 6 mm above the stylomastoid foramen
    → Enter tympanic cavity (via posterior canaliculus)
    → Pass forward adjacent upper part of tympanic membrane
    → Leaves tympanic cavity (via petrotympanic fissure)
    → ***Infratemporal fossa*** → Joins ***lingual nerve*** (of mandibular)

    ⇒ Contains
    1) Preganglionic parasympathetic fibers → ***Submandibular ganglion*** (relay) → postganglionic fibers → **Sublingual + submandibular** salivary glands.

       N.B. The parotid gland receives its innervation from the lesser petrosal nerve.

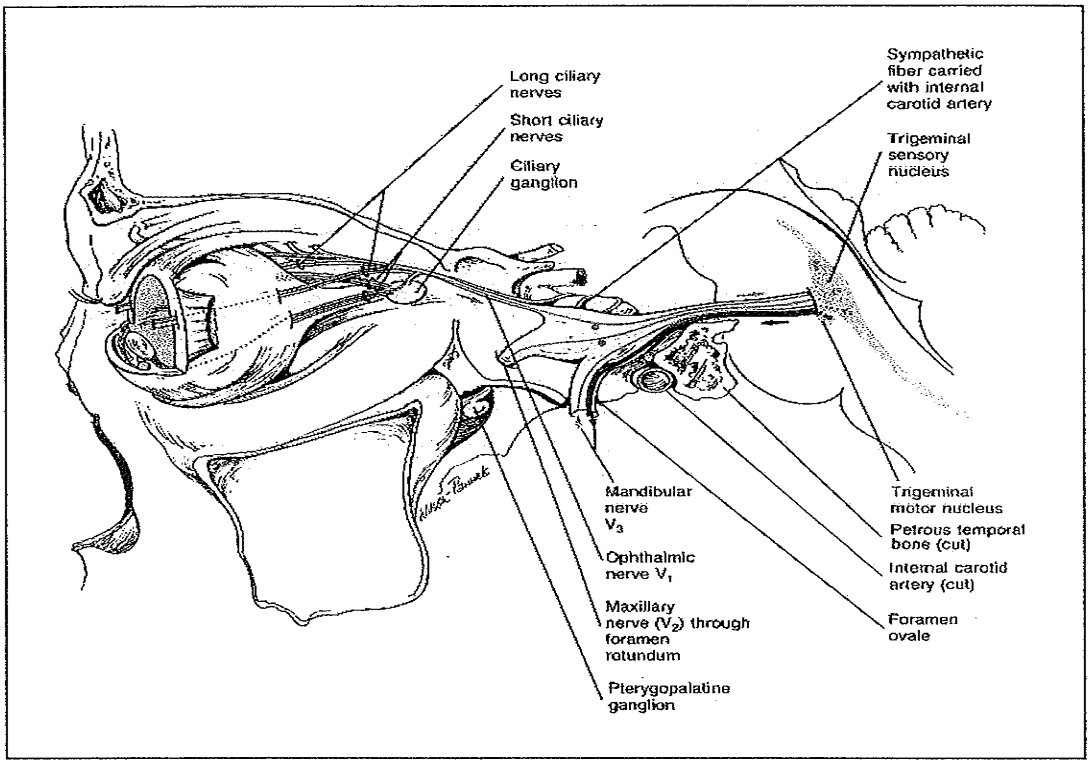
    2) Taste fibers from anterior 2/3 of the tongue.

       N.B. Other taste fibers are located in the petrous ganglion (glossopharyngeal n.) and in the nodose ganglion (vagus n.)

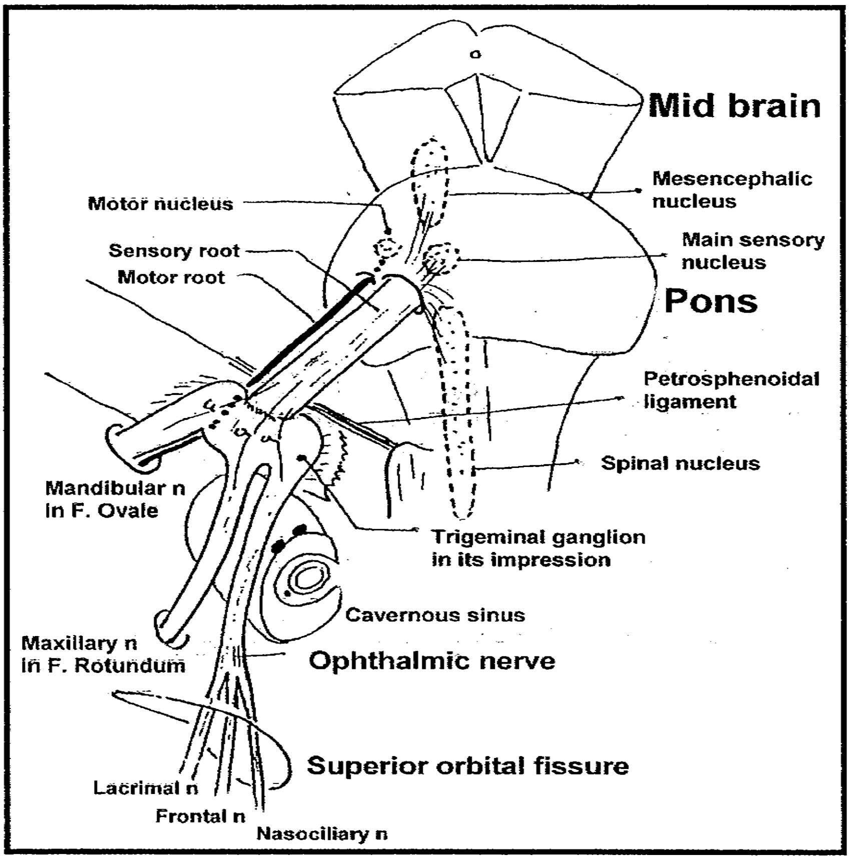
- **Below the stylomastoid foramen:**
  - Nerve to Posterior belly of Digastric.
  - Nerve to stylohyoid.
  - Posterior Auricular nerve → scalp muscles behind the auricle.
  - Terminal branches (inside the PAROTID)

    → **Upper temporofacial** → ***temporal*** and ***zygomatic*** branches (supplying the orbicularis oculi. the frontalis, the corrugator supercilii, and the anterior and superior auricularis muscles.)

    → **Lower cervicofacial** → lower face.



Long ciliary nerves
Short ciliary nerves
Ciliary ganglion
Sympathetic fiber carried with internal carotid artery
Trigeminal sensory nucleus
Mandibular nerve V3
Ophthalmic nerve V1
Maxillary nerve (V2) through foramen rotundum
Pterygopalatine ganglion
Trigeminal motor nucleus
Petrous temporal bone (cut)
Internal carotid artery (cut)
Foramen ovale



Mid brain
Motor nucleus
Mesencephalic nucleus
Sensory root
Motor root
Main sensory nucleus
Pons
Petrosphenoidal ligament
Spinal nucleus
Mandibular n in F. Ovale
Trigeminal ganglion in its impression
Cavernous sinus
Maxillary n in F. Rotundum
Ophthalmic nerve
Superior orbital fissure
Lacrimal n
Frontal n
Nasociliary n

Trigeminal (5th cranial) Nerve

(The largest cranial nerve)

Mixed nerve:

- **Motor fibers** →
  Muscles of mastication (masseter, temporalis, internal pterygoid, external pterygoid), Tensor tympani muscle, Tensor palatine muscle, Anterior belly of Digastric.
- **Sensory fibers** → From ant ½ of scalp + Face + Orbit + Oral cavity

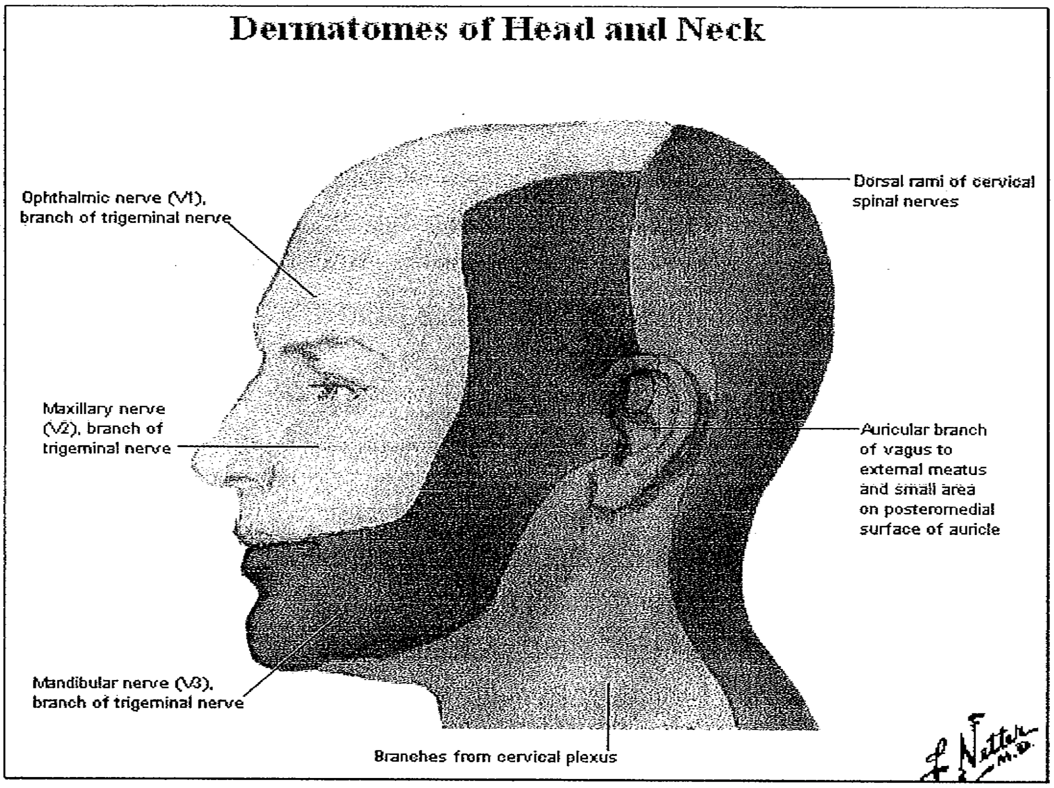
Nuclei of origin:

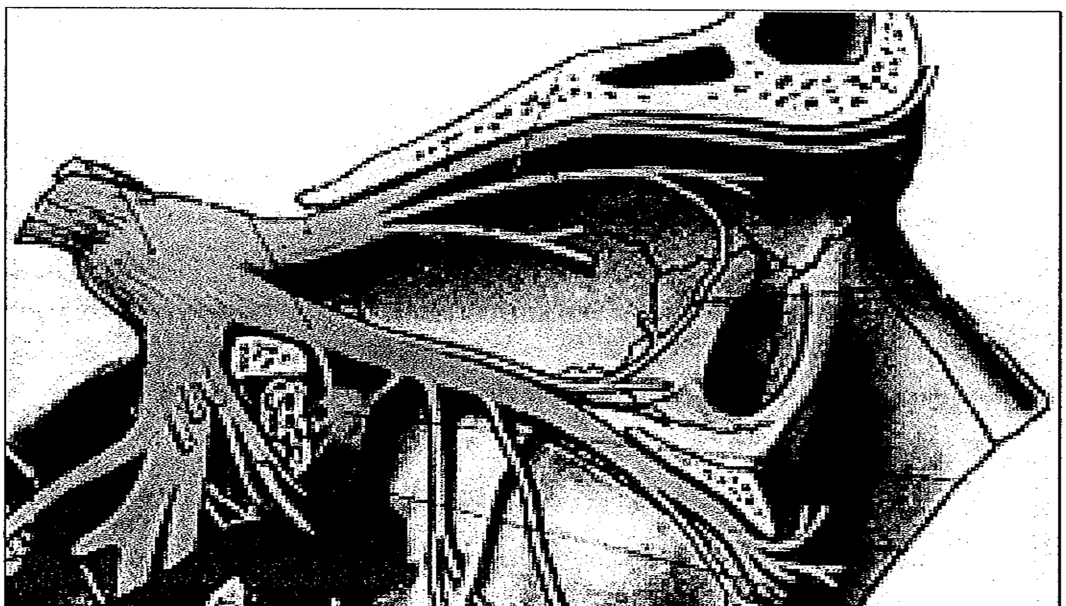
- **Motor** nucleus: *Mid pons.*
- **Sensory** nuclei:
  - *Mesencephalic nucleus (Midbrain + Upper pons)* → **Proprioception** (from muscles of mastication)
  - *Main sensory nucleus (Mid pons)* → **Touch**
  - *Spinal nucleus (lower pons + medulla + upper 2 segments of spinal cord,* ie. Continuous with S.G.R of the dorsal horn) → **Pain** + **Temperature**.

Course:

- ***In the brain stem***
  - It has 2 roots:
    - → *Sensory root* (large) → formed of the central process of the pseudounipolar cells in the trigeminal ganglion.
    - → *Motor root* (small) → fibers are distributed with Mandibular nerve.
  - Both roots emerge from the lateral surface of pons.

- ***Intracranial & extracranial course***
  - On emerging from the brain stem → Push the dura at the apex of petrous bone (below Superior petrosal sinus, above Petrosphenoidal ligament) → forming a dural pocket called Cavum Trigeminale. *(outpouching sac of the inner layer of Dura)*
  - **Trigeminal** ganglion (**Semilunar** ganglion = **Gasserian** ganglion)
    - → crescent-shaped mass of cells.
    - → lying in the trigemial impression on the anterosuperior surface of petrous bone.
    - → enclosed inside cavum trigeminale (Meckel cave).
    - → It has 2 borders:
      - ⇒ Posterior concave border → attached to sensory root that contains the central processes of pseudounipolar cells.
      - ⇒ Anterior convex border → attached to ophthalmic, maxillary & mandibular nerves that contain peripheral processes of the pseudounipolar cells.
  - The motor root passes below the ganglion to join the mandibular nerve.


Dermatomes of Head and Neck
Ophthalmic nerve (V1), branch of trigeminal nerve
Maxillary nerve (V2), branch of trigeminal nerve
Mandibular nerve (V3), branch of trigeminal nerve
Dorsal rami of cervical spinal nerves
Auricular branch of vagus to external meatus and small area on posteromedial surface of auricle
Branches from cervical plexus



The Ophthalmic Nerve (V_1)

(The smallest branch, Pure sensory)

Course:

- It starts at the trigeminal ganglion → passes forward in the lateral wall of the cavernous sinus (here it receives sympathetic branches from plexus surrounding I.C.A.)
- Just posterior to the superior orbital fissure, it receives the frontal, lacrimal, and nasociliary nerves. The frontal and lacrimal nerves leave the orbit above the ligament of Zinn, whereas the nasociliary branch leaves through the annulus of the ligament.

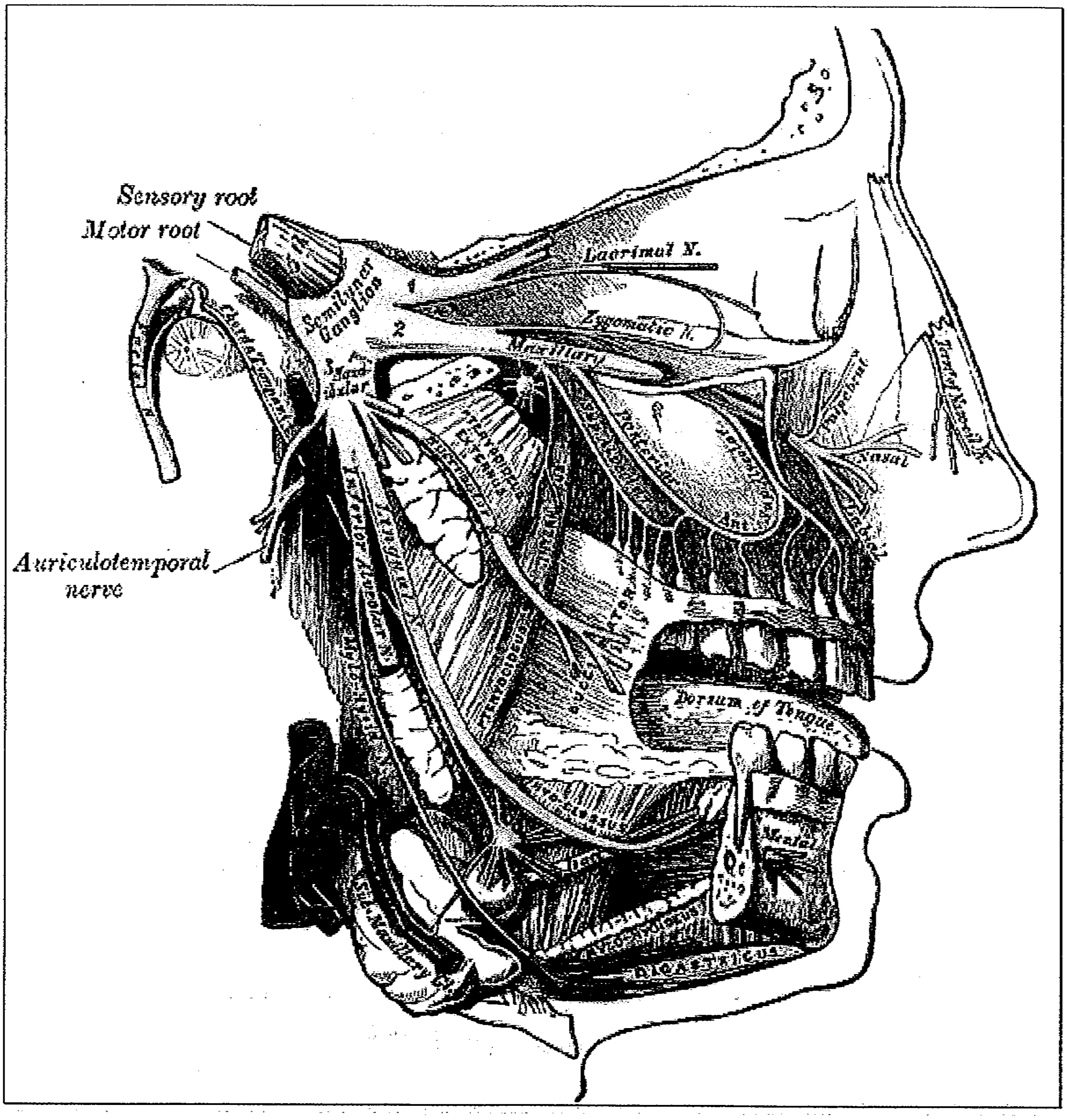
Branches: (It gives **meningeal branch** then devides into)

- **Frontal nerve:**
  - The largest.
  - Runs over Levator palpebrae superiosis.
  - Branches: In the middle of the orbit it divides into:
    - → *Supra-trochlear n.* → contains sensory nerves from the medial scalp, eyelid, and conjunctiva.
    - → *Supra-orbital n.* → supraorbital notch. (Its major branches ⇒ the ***medial and lateral frontal nerves*** ⇒ receive sensory impulses from the forehead, scalp & upper eyelid)
- **Nasociliary nerve:**
  - Medium sized
  - Passes forwards and medially (with the ophthalmic a.) crossing over optic n.
  - Branches:
    - → *Sensory root* to ciliary ganglion.
    - → *2 Long ciliary nerves* → Sensory to the globe + Sympathetic to dilator pupillae ms.
    - → *Posterior ethmoidal n.* → Posterior Ethmoidal Foramen → mm. of sphenoidal & ethmoidal sinuses.
    - → *Anterior ethmoidal n.* → Anterior ethmoidal foramen → cranial cavity → nasal cavity
      - ⇒ Internal nasal n. → Nasal mucous membrane.
      - ⇒ External nasal n. → skin over nasal cartilage. (tip of the nose)
    - → *Infratrochlear n.* → Superior and inferior palpebral nerves.
- **Lacrimal nerve:**
  - The smallest.
  - Runs over the upper border of Lateral rectus (with lacrimal a.)
  - Branches:
    - → *Superior branch* (the ***lateral palpebral nerve***) → sensory from the skin and conjunctiva of the upper and lower eyelids.
    - → *Inferior branch*
      - ⇒ Sensory supply to lacrimal gland.
      - ⇒ Receives postganglionic parasympathetic twig from Zygomatico temporal n. → Secretory to lacrimal gland.

Applied anatomy

Headache in corneal ulcer is a referred pain through meningeal branches of ophthalmic

Hutchinson sign = involvement of external nasal nerve in herpes zoster ophthalmicus → it is a dangerous sign because it is a terminal branch & as herpes zoster reaches it, there is mostly ocular complications.


Sensory root
Motor root
Semilunar Ganglion
Lacrimal N.
Zygomatic N.
Maxillary
Auriculotemporal nerve
Dorsum of Tongue
Mental
DIGASTRICUS

Maxillary Nerve (V_2)

(Medium sized, Pure sensory)

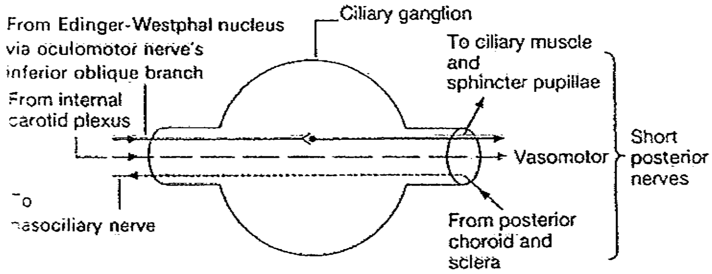
Course:

- It starts at the ***trigeminal ganglion*** → pass forward in the lateral wall of the cavernous sinus → *Foramen rotundum* → ***Pterygo-palatine fossa*** → *Pterygo-maxillary fissure* → ***Infratemporal fossa*** → *inferior orbital fissure* → continues as ***Infra-orbital nerve***.

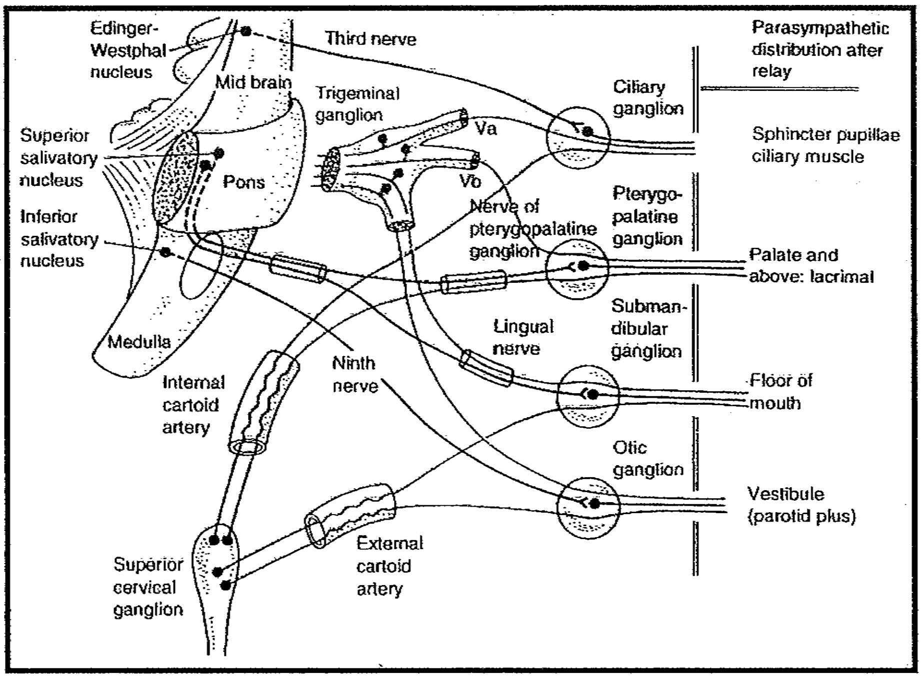
Branches:

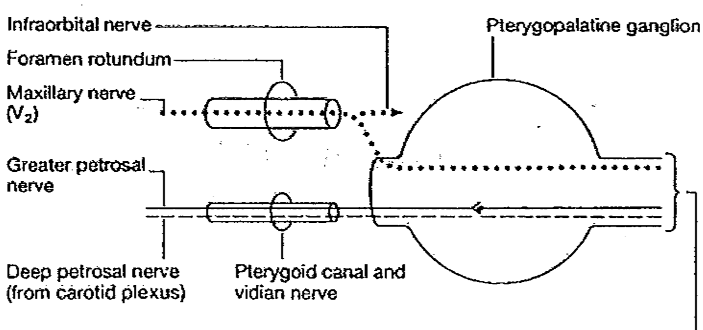
- In the cranial cavity → meningeal branch.
- In the pterygo-palatine fossa:
  - 2 sensory roots → spheno-palatine ganglion.
  - Posterior superior alveolar
  - Zygomatic nerve → IOF → zygomatic groove → zygomatic foramen → zygomatic canal
    - ⇒ Zygomatico-facial n. → skin over zygomatic bone.
    - ⇒ Zygomatico-temporal n. → skin of the anterior ½ of temple.
- Infra orbital nerve (its continuation)
  - Passes through the ***inferior Orbital fissure*** → ***infraorbital groove*** → ***infraorbital canal*** → ***infraorbital foramen.***
  - Branches:
    - ⇒ Middle superior alveolar n.
    - ⇒ Anterior superior alveolar n.
    - ⇒ Terminal (Nasal, ***Palpebral***, Labial)

- All orbital contents are enclosed inside the periostem except ***Zygomatic n.*** & ***Infraorbital n***.
- ⇒ Deep petrosal n.(plexus around ICA) → sympathetic to spheno-palatine ganglion.
- ⇒ Greater petrosal n. (facial) → parasympathetic to spheno-palatine ganglion.
- ⇒ Lesser petrosal n. (Glossopharyngeal) → parasympathetic to Otic ganglion.



The ciliary ganglion. (—) Parasympathetic fibres; (– –) sympathetic fibres; (· · · ·) sensory fibres





Branches	*Destination*
Lacrimal	Lacrimal gland
Pharyngeal	Pharyngeal mucosa
Posterior superior nasal	Lateral nasal wall and septum
Nasopalatine	Palate and nasal septum
Greater palatine	Hard palate
Lesser palatine	Soft palate

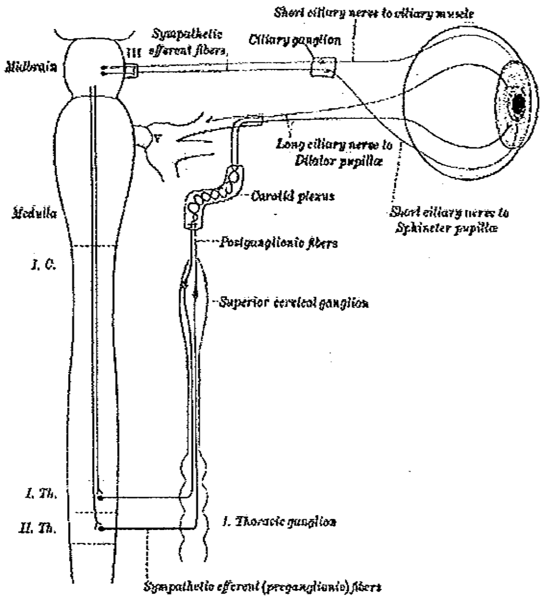
The pterygopalatine ganglion. (—) Parasympathetic fibres; (– –) sympathetic fibres; (· · · ·) sensory fibres

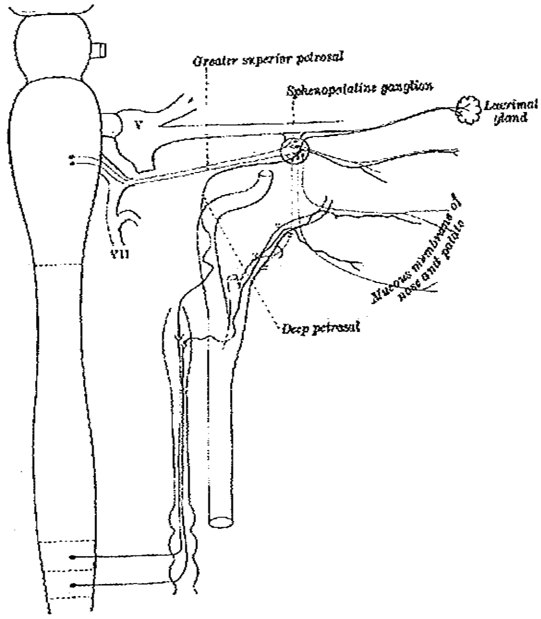
Ciliary Ganglion

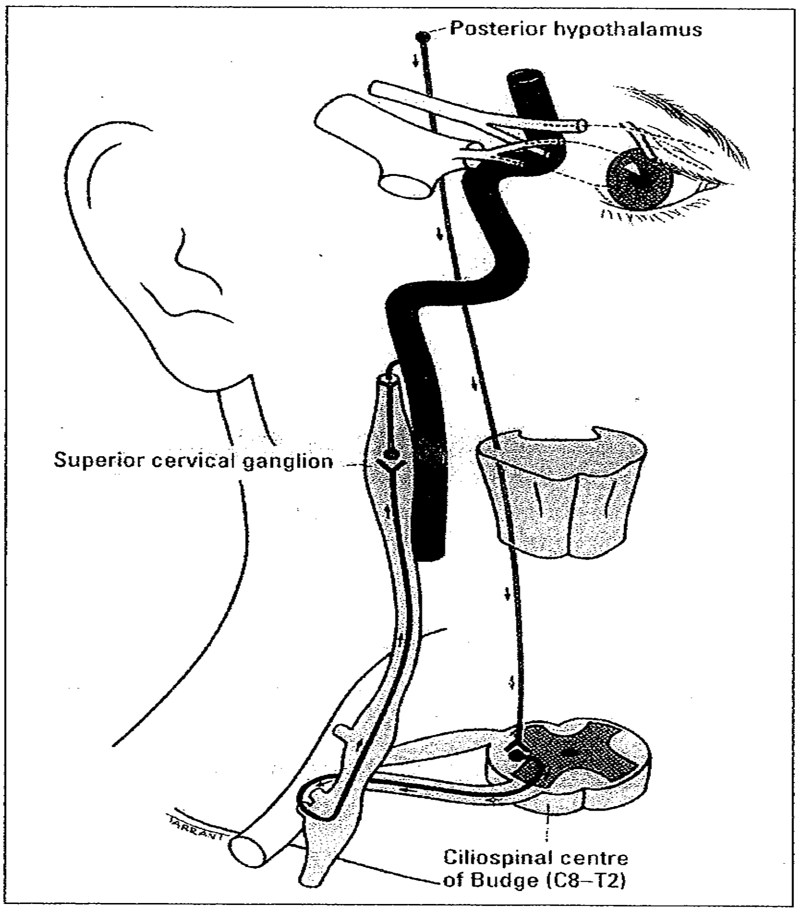
- The **Smallest** Parasympathetic ganglion of the head and neck (1-2 mm in diameter)
- **Location** ⇒ Between ***optic nerve*** and ***lateral rectus***.
- **Roots & branches:**
  - **Sensory** root: (the sensory root also contain sympathetic fibers that may entirly replace the separate sympathetic root)
    ⇒ From nasociliary n. ⇒ no relay ⇒ Sensory to Posterior sclera (mainly), Iris & Cornea.
  - **Sympathetic** root:
    ⇒ From nasociliary n. ⇒ no relay ⇒ Vasomotor to eye ball blood vessels. (Choroidal blood vessels)
  - **Parasympathetic** root:
    ⇒ From nerve to inf. Oblique ⇒ relay ⇒ Constrictor pupillae + Ciliary muscle.
- The branches of the ciliary ganglion are ***6 to 20 short ciliary nerves*** → pierce the sclera around the optic nerve → distributed to the uveal tract and to the ciliary and sphincter pupillae muscles.

Spheno-palatine Ganglion

- The **Largest** Parasympathetic ganglion of the head and neck
- **Location** ⇒ ***Pterygo-palatine fossa***
- **Roots & branches:**
  - **Sensory** root:
    ⇒ From maxillary n. ⇒ no relay ⇒ Sensory to Orbital periosteum + Nasal mm. & nasopharynx
  - **Sympathetic** root:
    ⇒ From deep petrosal n. ⇒ no relay ⇒ Vasomotor.
  - **Parasympathetic** root:
    ⇒ From greater superficial petrosal n. ⇒ relay ⇒ Nasal, **Lacrimal**, Palatine & Nasopharyngeal glands
- **Branches:**
  - **Orbital branches** → Inferior orbital fissure → Sensory to orbital periosteum
  - Post-ganglionic parasympathetic fibers → Join maxillary nerve → Zygomatico-temporal nerve → Lacrimal nerve → **Lacrimal gland**
  - **Greater & lesser palatine nerves** → Greater & lesser palatine canals → Sensory to **palate** & secretory to palatine glands.
  - **Long & short spheno-palatine nerves** → Spheno-palatine foramen → Sensory to **nasal** mm. & secretory to nasal glands
  - **Pharyngeal branches** → Palatino vaginal canal → Sensory to **nasopharynx** & secretory to its glands.


Short ciliary nerve to ciliary muscle
Sympathetic efferent fibers
III
Ciliary ganglion
Midbrain
V
Long ciliary nerve to Dilator pupillæ
Carotid plexus
Short ciliary nerve to Sphincter pupillæ
Medulla
Postganglionic fibers
I. C.
Superior cervical ganglion
I. Th.
II. Th.
I. Thoracic ganglion
Sympathetic efferent (preganglionic) fibers


Greater superior petrosal
Sphenopalatine ganglion
Lacrimal gland
V
VII
Mucous membrane of nose and palate
Deep petrosal


Posterior hypothalamus
Superior cervical ganglion
Ciliospinal centre of Budge (C8–T2)

Autonomic Nervous System

Parasympathetic nervous System

⇒ ***Edinger-Westphal nucleus*** (of oculomotor nerve) ⇒ ***Preganglionic fibers*** (pass with Inferior division of oculomotor) → nerve to inferior oblique ⇒ short motor root of ciliary ganglion ⇒ ***ciliary ganglion*** (synapse) ⇒ ***postganglionic fibers*** ⇒ ***short ciliary nerves*** (6-20) ⇒ ciliary muscle and sphincter pupillae muscle.

⇒ ***Lacrimal (Superior salivalory) nucleus*** (of facial nerve) ⇒ ***Preganglionic* fibers** (pass with nervus intermedius part of facial nerve) ⇒ geniculate ganglion (no relay) ⇒ ***greater superficial petrosal n.*** ⇒ ***nerve of pterygoid canal*** ⇒ ***sphenopalatine ganglion*** (synapse) ⇒ ***postganglionic fibers*** Join maxilary nerve ⇒ ***Zygomatico-temporal** branch* ⇒ ***Lacrimal n.*** ⇒ ***Lacrimal Gland.***

Sympathetic nervous system

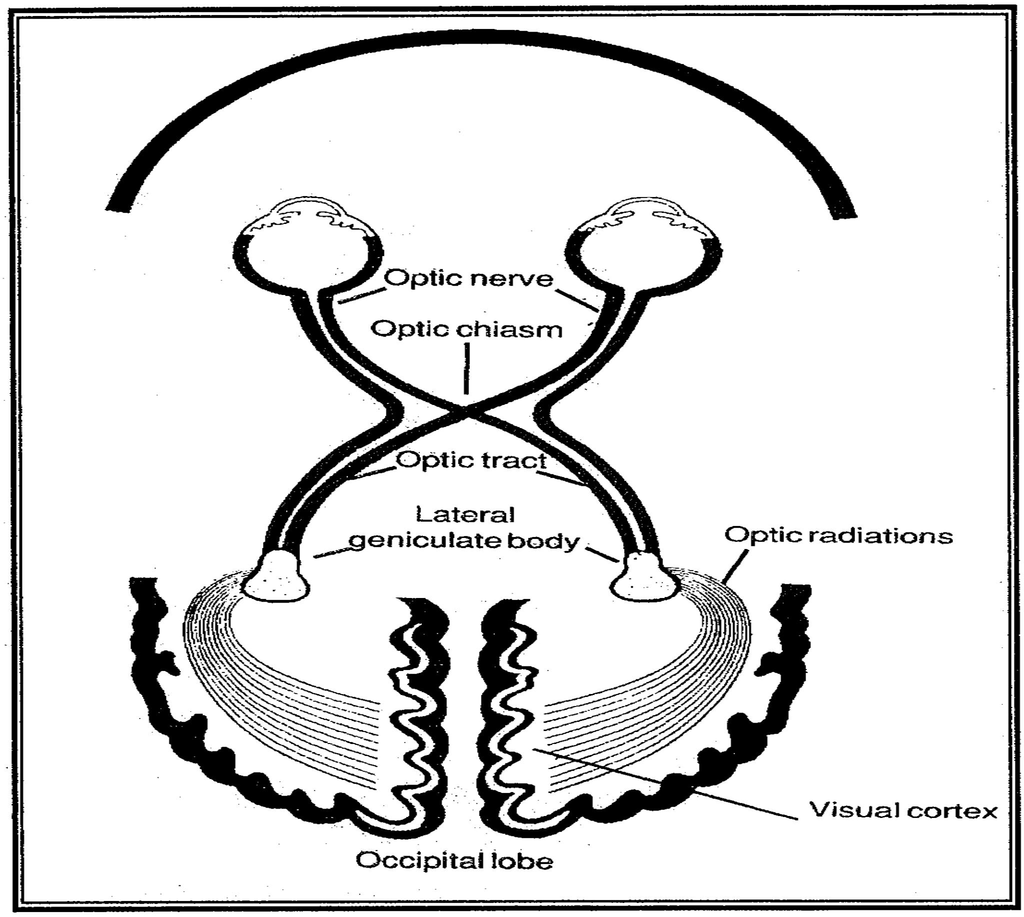
- **Center :** Posterior hypothalamus
- **Pathway :** Three neurons
  - **Central**: From ***Posterior hypothalamus*** → Ciliospinal center of Budge (in the lateral horn of the spinal cord between C_8- T_2)
  - **Preganglionic fibers**: From ***Ciliospinal center of Budge*** → Superior cervical sympathetic ganglia (the fused ganglia in the sympathetic chain at the level of $C_{1,2,3}$)
  - **Postganglionic fibers**: From ***Superior cervical sympathetic ganglia*** → fibers are distributed with:

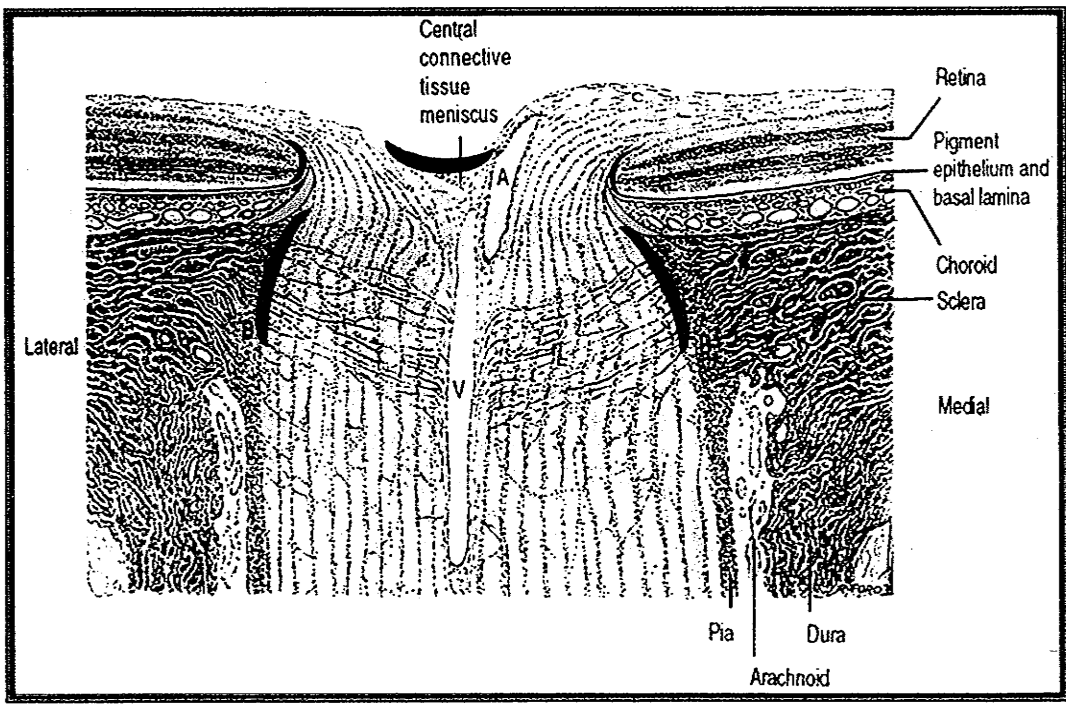
⇒ The internal carotid branches ⇒ Fibers to the eye and the orbit.

- **Nasociliary nerve**
  - → Sympathetic root to ciliary ganglion → no relay → short ciliary nerves → vasomotor to ***choroidal blood vessels***
  - → Two long ciliary nerves → ***Dilator pupillae muscle***
- **Oculomotor nerve** → Nerve to levator muscle → ***Muller's muscle***
- **Ophthalmic artery** → medial & lateral palpebral arteries → Lid & conjunctival vessels

⇒ The external carotid artery ⇒ Fibers for sweating of the face.

N.B. Postganglionic Horner $ will not cause facial anhydrosis because postganglionic fibers for facial sweeting travel with ECA.


Optic nerve
Optic chiasm
Optic tract
Lateral geniculate body
Optic radiations
Visual cortex
Occipital lobe


Central connective tissue meniscus
Retina
Pigment epithelium and basal lamina
Choroid
Sclera
Lateral
Medial
A
B
C
V
Pia
Dura
Arachnoid

VISUAL PATHWAY

Optic Nerve (2nd cranial nerve)

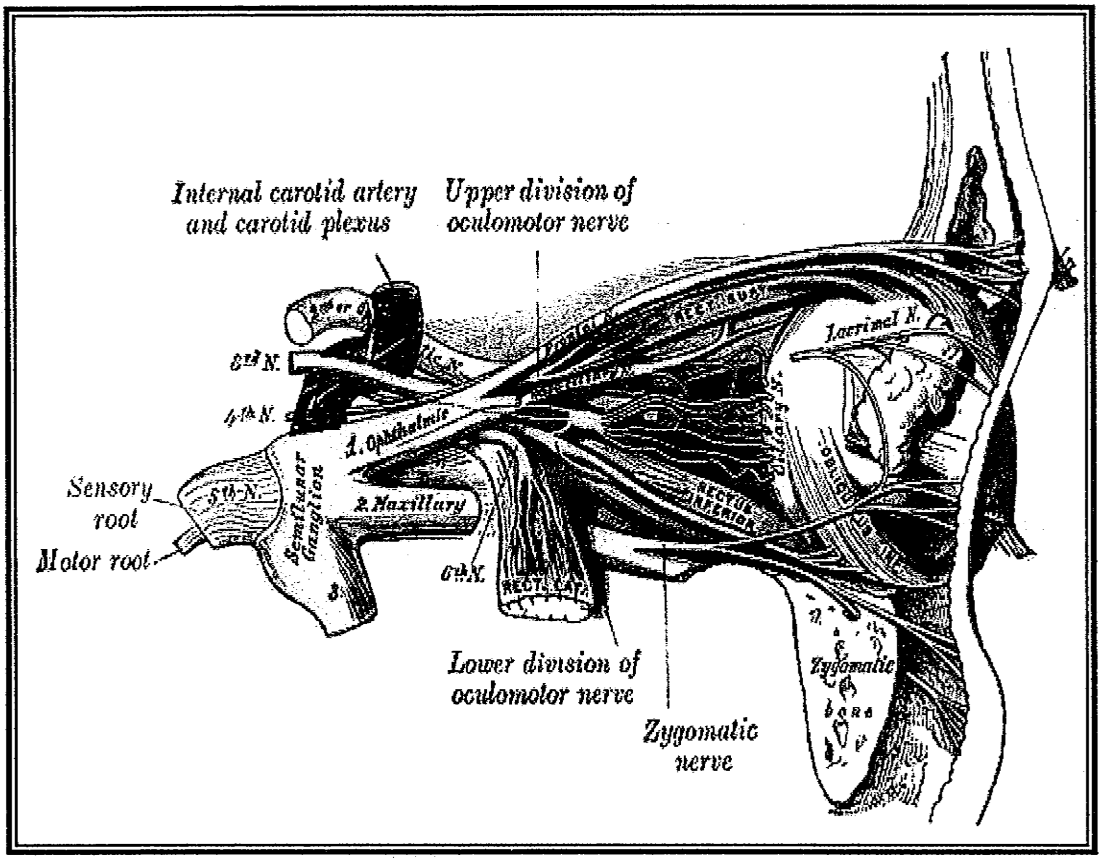
□ Definition:

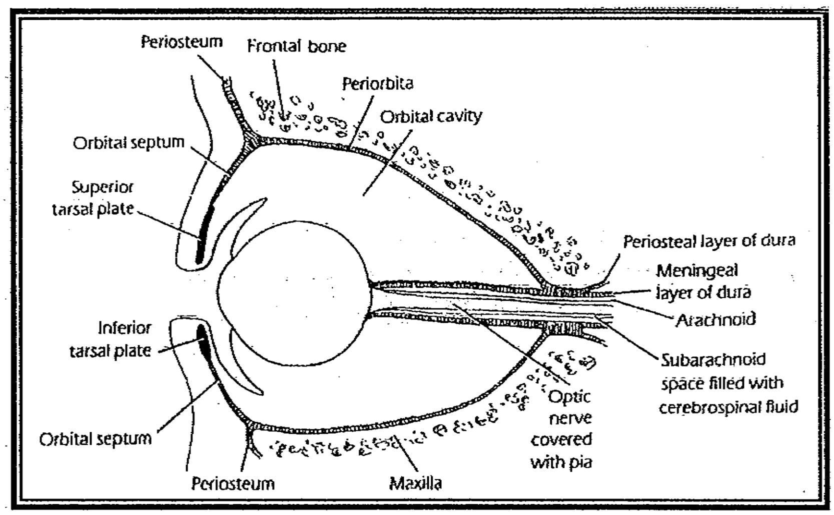
- It is white fiber <u>tract of the C.N.S</u>
  - (1) Meningeal sheath
  - (2) No neurolemmal sheath → cant regenerate
  - (3) Embryologicaly → outgrowth of brain
  - (4) Tumours → Meningiomas
- Composed of axons of retinal ganglion cells.
- Extends from the optic disc to the optic chiasm.

□ Portions:

- **Intraocular portion** (1 mm length) (1.5 mm diameter)

  - ◘ Includes: Optic disc + The portion of the optic nerve within the posterior scleral foramen.
  - ◘ Divided into: *<u>Pre-laminar</u>*, *<u>laminar</u>* & *<u>post-laminar</u>* or *<u>retinal</u>*, *<u>choroidal</u>* & *<u>scleral</u>* parts.
  - ◘ The ***<u>optic disc</u>***:
    - ⇒ Diameter: about 1.5 mm
    - ⇒ Location: about 3 mm nasal to & about 0.8 mm above the foveola. (Posterior pole)
    - ⇒ It represents the blind spot in visual field testing (due to absent photoreceptors)
    - ⇒ The choroid and all layers or the retina (except NFL) terminate at the optic disc margin.
      - The RPE may stop peripheral to the choroid ⇒ ***<u>Choroid crescent</u>*** if accumulates ⇒ ***<u>Pigmented crescent</u>***
      - The RPE & Choroid may stop before sclera ⇒ ***<u>Scleral crescent</u>***
    - ⇒ Posterior to it nerve fibers are myelinated, anterior to it they are not myelinated.
  - ◘ The optic nerve leaves the eye through the ***posterior scleral foremen*** that is bridged with the ***<u>lamina cribrosa</u>*** (giving the <u>white pinkish</u> colour of the disc) formed by:
    - → <u>fibrous tissue</u> from the *sclera* → posteriorly
    - → <u>elastic tissue</u> of the *choroid & Bruch membrane*, and
    - → <u>astroglia</u> derived from the *septal system of the nerve* → anteriorly
  - ◘ Central portion of the disc is separated from
    Vitreous by → ***Central C.T meniscus of kuhnt.*** (From *astrocytes* = neuroectodermal) (instead of ILM)
  - ◘ Margin of intraocular part is separated from
    Retina by → ***Intermediate tissue of Kuhnt*** (From *astrocytes* = neuroectodermal)
    Choroid (basal lamina) by → ***Border tissue of Jacoby*** (From *astrocytes* = neuroectodermal)
    Choroid & ant 1/3 of **Sclera** by → ***Marginal tissue of Elschnig.*** (From *sclera* = mesodermal)

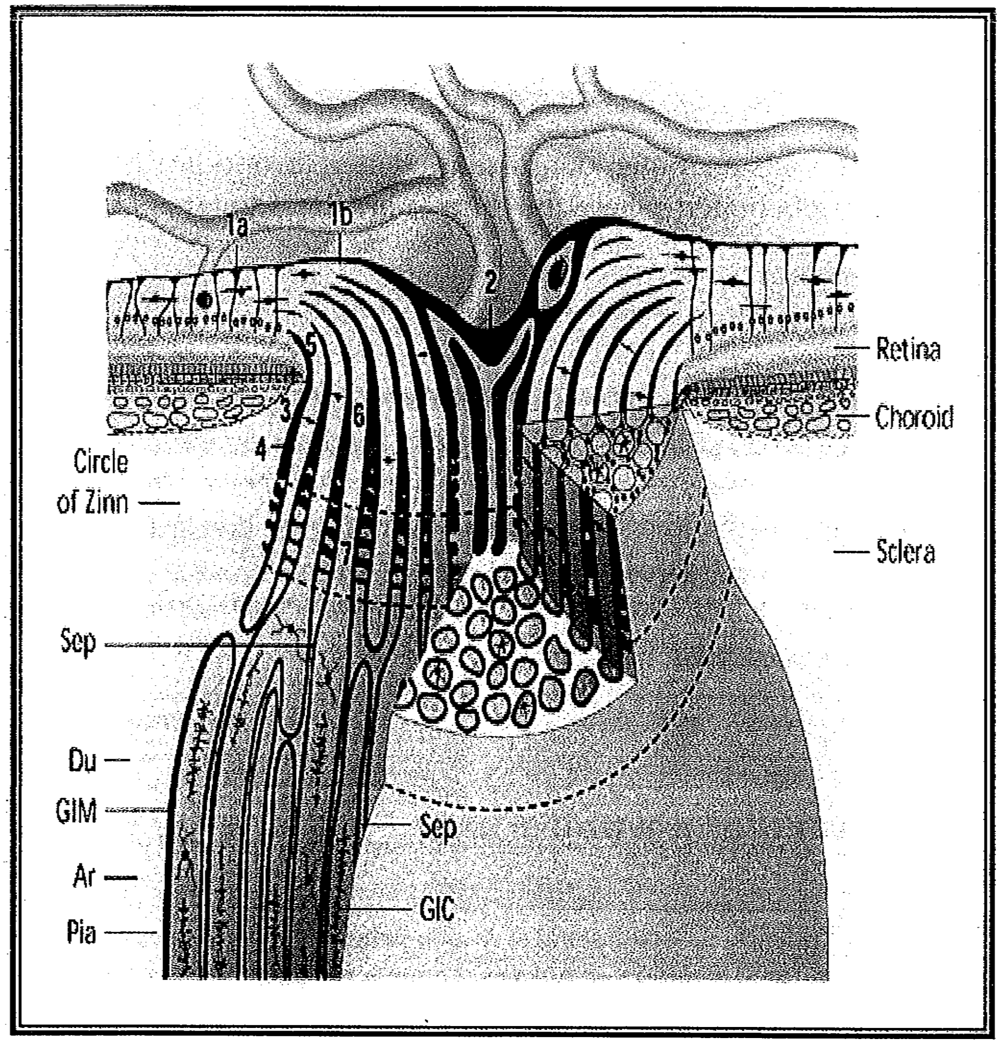

Internal carotid artery and carotid plexus
Upper division of oculomotor nerve
Sensory root
Motor root
Lower division of oculomotor nerve
Zygomatic nerve

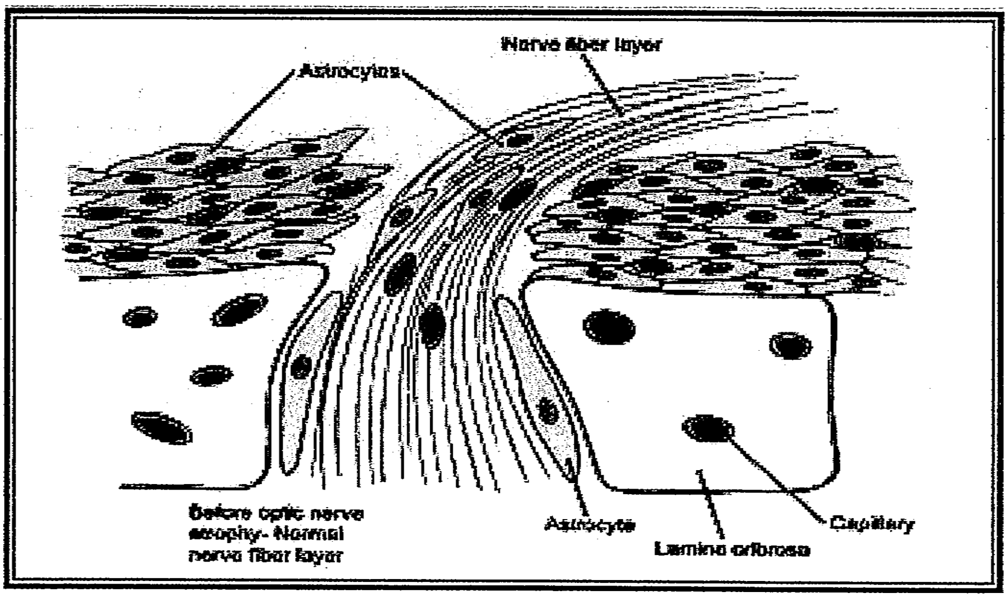

Periosteum
Frontal bone
Periorbita
Orbital cavity
Orbital septum
Superior tarsal plate
Periosteal layer of dura
Meningeal layer of dura
Arachnoid
Subarachnoid space filled with cerebrospinal fluid
Inferior tarsal plate
Orbital septum
Optic nerve covered with pia
Periosteum
Maxilla

- **Orbital portion** (30 mm length) (3-4 mm diameter due to myelination)
  - *S-shaped curve* → permits movements of the eye.
  - *Sheathed* with an outer dense dura mater, a middle arachnoid mater & an innermost pia mater, where the dura & arachnoid matters blend into the sclera. *(superior & medial recti partially originate from the nerve sheath → pain with eye movement in retrobulbar neuritis)*
  - *Relations*
    - ⇒ At the globe → long & short ***ciliary arteries & nerves*** are arranged by its circumference.
    - ⇒ 12 mm behind the globe → ***CRA & CRV*** penetrate the infero-medial side of optic n. ⇒ *Increased CSF pressure is transmitted to CRV as it crosses the subarachnoid space ⇒ Papilloedema*
    - ⇒ At the apex of the orbit → Surrounded by the ***fibrous annulus of zinn*** (origin of recti)
    - ⇒ Between the optic nerve and lateral rectus: **(1)** Oculomotor inf. & sup. divisions **(2)** abducent **(3)** nasociliary n. **(4)** Ciliary ganglion **(5)** Sympathetic n. to ciliary ganglion **(6)** ophthalmic a. & vs..
    - ⇒ The nerve is crossed
      - → **Above** → **1)** Nasociliary n. **2)** Ophthalmic artery (85%) **3)** Sup.ophthalmic v.
      - → **Below** → **1)** N. To medial rectus **2)** Ophthalmic artery (15%)

- **Intracanalicular portion** (6 mm)
  - Relations:
    - o **Infero-laterally** ⇒ ophthalmic a. & sympathetic nerves accompanying this a.
    - o **Medially** ⇒ *Sphenoidal* or *posterior ethmoidal* sinus (separated by a thin plate of bone) ⇒ *Retro-bulbar neuruits* may occur in *sinusitis*.
  - At the anterior margin of the optic foramen the dura covering the nerve splits so that
    - → One portion continues as the ***periosteum*** of the orbit
    - → The other continues as the ***dural sheath*** of the optic nerve. Which is adherent to bone (externally) & to arachnoid and pia mater (internally) ⇒ so the nerve is firmly fixed. ⇒ *It is the part which may undergo avulsion*

- **Intracranial portion** (10 mm) → passes backward & medially to form the chiasma.
  - Relations
    - o Above.
      1) Anterior perforating substance.
      2) Medial root of olfactory tract.
      3) Anterior cerebral artery.
      4) Frontal lobe.
    - o Below.
      1) Diaphragma sellae. 2) Cavernous sinus. 3) Ophthalmic artery.
    - o Below & lateral.
      1) Internal carotid artery. 2) Ophthalmic artery.


1a
1b
2
3
4
5
6
7
Retina
Choroid
Circle of Zinn
Sclera
Sep
Du
GlM
Ar
Pia
Sep
GlC


Nerve fiber layer
Astrocytes
Before optic nerve atrophy- Normal nerve fiber layer
Astrocyte
Capillary
Lamina cribrosa

Structure :

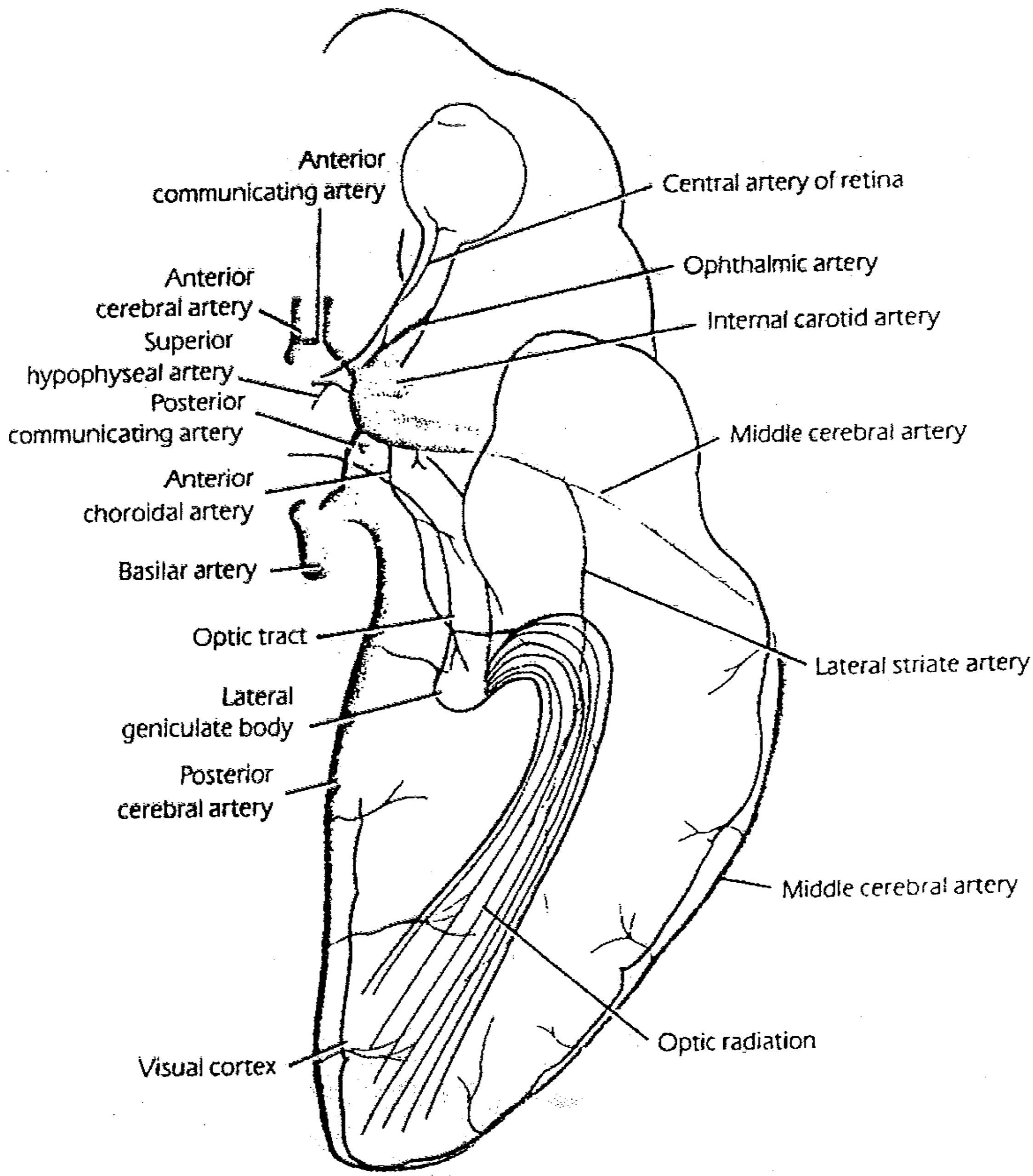
- **Afferent axons** of ganglion cells
  - 1.2 million (Axons of *macular* ganglion cells **(1)** Constitute 1/3 of the nerve **(2)** Laterally placed in the nerve **(3)** Centrally placed in the nerve near the chiasma)
  - Synapse in
    → Lateral geniculate body (vision fibers)
    → Pretectal nuclei (pupillary fibers)
  - 600 **bundles** (each containing 2000 fibers)
  - Separated by **septa** that are continuous with the pia mater.
    ⇒ *Structure* → (Central blood vessel, surrounded by C.T, surrounded by glial tissue)
    ⇒ *Types* :
      → Primary (6-9) → divides the nerve into sectors.
      → Secondary → divides the nerve into bundles.
    ⇒ Septal system & trabeculae *disappear* at the begining of the physiological chiasma (where the crossed fibers first separate from the uncrossed) anterior to macroscopic chiasma

- **Astrocytes** (from neuroectoderm) ⇒ ***Skeletal framework & mechanical support***
  ⇒ Fill the space between axons
  ⇒ Form a glial sheets between:
    → Vitreous & central portion of the disc → ***central C.T meniscus of kuhnt***
    → Retina & optic nerve → ***Intermediat tissue of Kuhnt***
    → Choroid & optic nerve → ***border tissue of Jacoby***
  ⇒ Fill the empty space when the axons are lost in optic atrophy
  ⇒ N.B. No Muller's cells in the disc → Disc swells easily in papilloedema while the retina remains flat (Muller's cells connect axons at right angle to their course)

- **Oligodendroglia** (from neuroectoderm) ⇒ ***Synthesis & metabolism of myelin***
  ⇒ These cells are most numerous behind the lamina cribrosa. (Myelination of the optic nerve begins at the chiasm at about the 24th week of fetal life and, at birth, has reached a point just behind the lamina cribrosa.)
  ⇒ Not present in retinal nerve fiber layer → if present → congenital myelination of retinal nerve fibers.

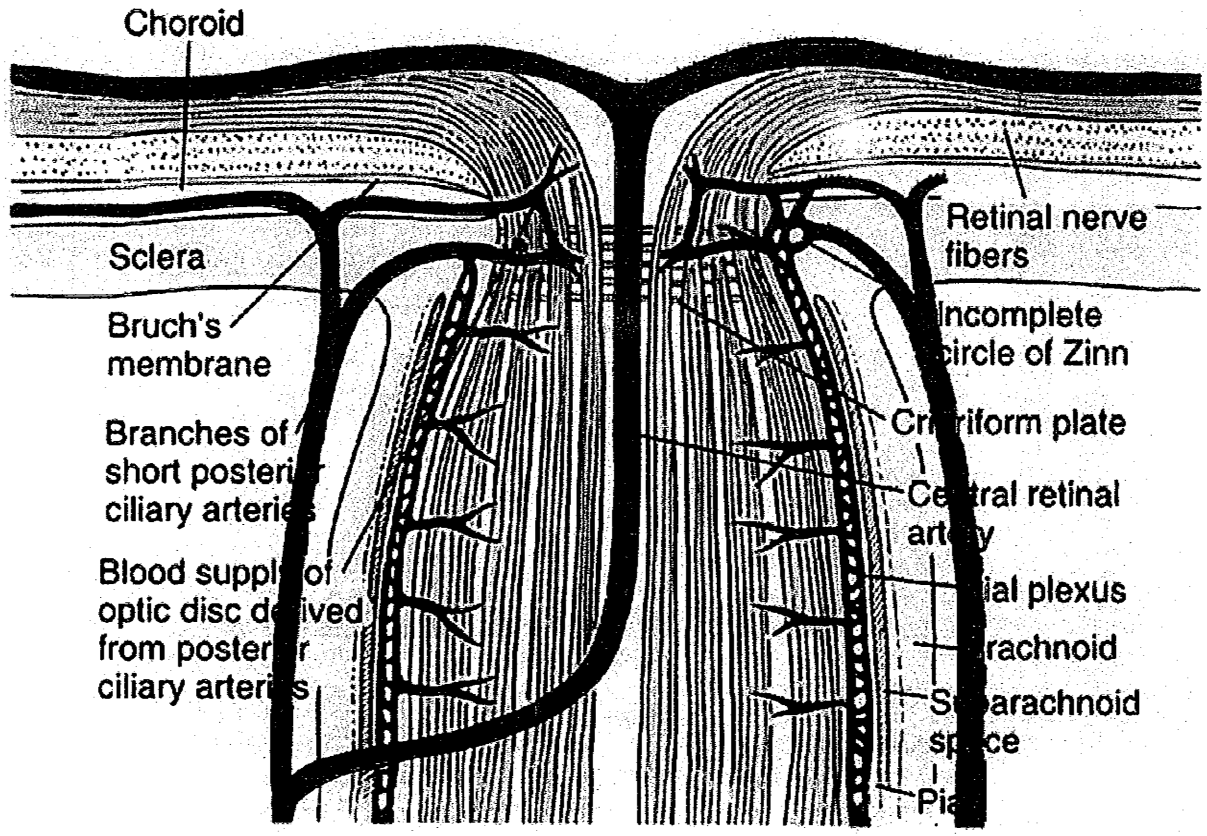
- **Microglia** (mesenchymal origin) ⇒ ***Phagocytic function***
  ⇒ Modulate apoptosis of retinal ganglion cells

- **Sheaths**



Blood supply of the visual pathway

	Dura	Arachnoid	Pia	Subarachnoid
Thickness	0.5 mm	10 µm		
Surrounds optic n.	Canalicular & Orbital parts	Canalicular & Orbital parts	All Parts	Canalicular & Orbital parts
Termination	Continuous with the ***outer 2/3 of sclera***. Don't run parallel to the scleral fibers, but interlace & blend with them.	Continuous with the ***sclera*** at the level of the *posterior part of lamina cribrosa.*	Continuous with the ***sclera*** *(inner 1/5 or 2/5)* But some fibers with ***Choroid*** some with ***Marginal tissue of Elsching***	Ends in ***Cul-de-sac*** which : lies in the sclera & whose : anterior extremity reaches the back of lamina cribrosa.
Course	1) **Firmly adherent** to the periosteum of the canal 2) **Splits** at the anterior margin of the canal → outer portion continuous with orbital periostem & inner portion continues as dura of optic n.			
Structure	***Bundles of fibrous tissue*** (larger than scleral) 2) Formed of → • Collagen • Elastic • Cells (flat or star shaped) 3) Arranged as → • Inner circular • Middle oblique • Outer longitudinal ***Inner surface*** of the dura lined by endothelium ***Outer surface*** is separated from orbital fat by *supravaginal space of schwalbe.*	***Central core of noncellular collagenous tissue*** ***Surface facing the dura*** covered by *multilayered epithelial cells* may proliferate ↓ endothelial pearls (corpora amylacea) ***Surface facing CSF*** covered by (1) complete mesothelium (2) uncomplete basal lamina	***Vascular loose C.T*** 1) Formed of → • Collagen • Elastin • Reticulin 2) Arranged as → • Inner longitudinal • Outer circular • Vessels in between ***Outer surface*** of pia lined by endothelium ***Inner surface*** with glia forms → *pia glia* → sends numerous septa inbetween optic nerve bundles.	

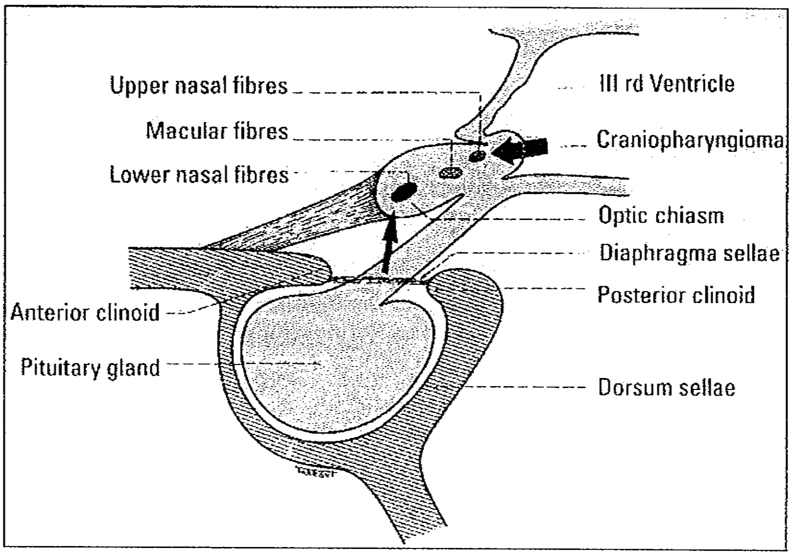

Choroid
Sclera
Bruch's membrane
Branches of
short posteri
ciliary arteri
Blood suppl
optic disc d
ived
from poster
ciliary arteri
Retinal nerve fibers
Incomplete
ircle of Zinn
Cr
iform plate
Ce
tral retinal
ial plexus
rachnoid
S
arachnoid
ce
Pi

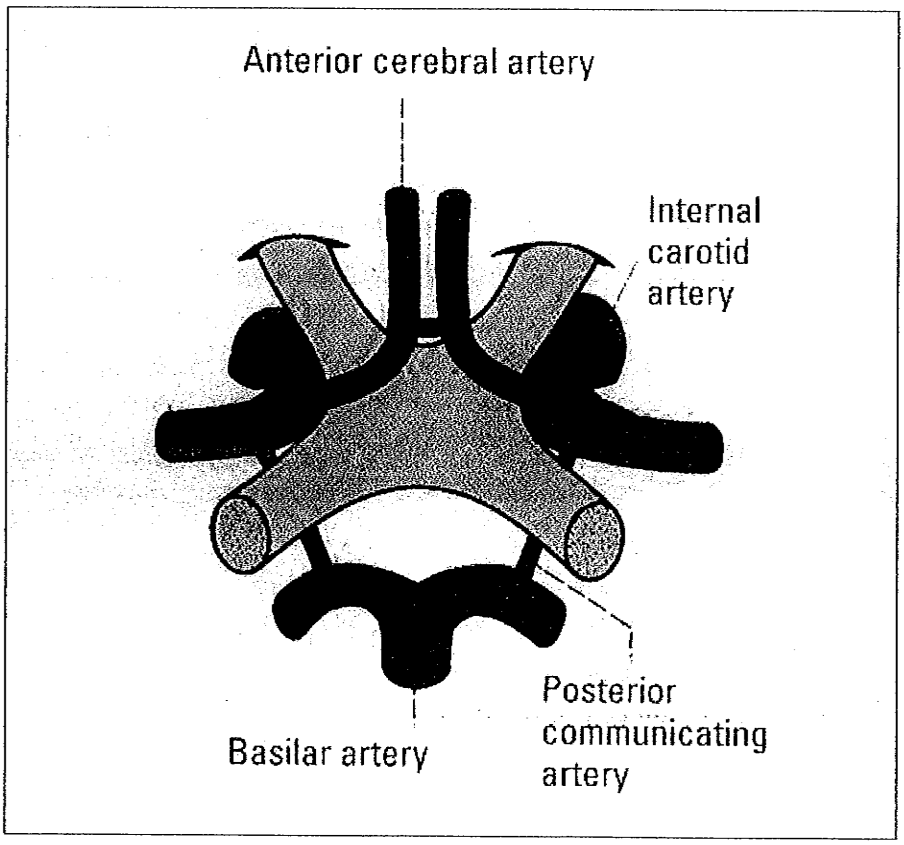
□ Blood supply :

- **Intraocular** portion → ***Anastomotic Circle of Haller-Zinn*** formed of
  - Short posterior ciliary arteries (mainly)
  - Pial branches of central retinal artery.
- **Intraorbital** portion →
  - **Peripheral** vessels ⇒ derived from those of the ***pia mater*** and are derived from the neighboring branches of ophthalmic a..
  - **Axial** vessels ⇒ derived from the ***central retinal artery***
    - → *Extraneural part gives → central collateral arteries*
    - → *Intraneural part gives → few small branches.*
- **Intracanalicular** & **Intracranial** portions → *Pial fibrovascular meshwork* from branches of:
  1) **Internal carotid artery.**
  2) Ophthalmic artery.
  3) Anterior cerebral.
  4) Superior hypophyseal.

□ Applied anatomy :

- ***Glaucomatous cupping*** *→ because Lamina cribrosa becomes bowed backwards in glaucoma*
- ***Pain with eye movement in retrobulbar neuritis*** *→ superior & medial recti partially originate from the nerve sheath (if no meningeal inflamation → no pain)*
- ***Increased CSF pressure*** *is transmitted to CRV as it crosses the subarachnoid space ⇒ Papilloedema*
- ***Sinusitis may lead to Retrobulbar neurits*** *→ Because Sphenoidal* or *posterior ethmoidal* sinus are medial to the optic canal (separated by a thin plate of bone)
- ***Avulsion of optic nerve occurs at its intracanalicular portion*** *→ because dura is firmly adhenrent to bone (externally) & to arachnoid and pia mater (internally)*
- ***Widening of the optic canal***
  - *Tumours of optic nerve with intra-cranial extension*
  - *Aneurysm of the ophthalmic artery → pulsatile exophthalmos*
- ***Surgical approach to optic nerve tumours***
  - *Trans-orbital approach (lateral)*
  - *Trans-cranial approach (in intracranial extension)*


Upper nasal fibres
Macular fibres
Lower nasal fibres
III rd Ventricle
Craniopharyngioma
Optic chiasm
Diaphragma sellae
Posterior clinoid
Anterior clinoid
Pituitary gland
Dorsum sellae


Anterior cerebral artery
Internal carotid artery
Posterior communicating artery
Basilar artery

Optic Chiasma

- **Definition** ⇒ Quadrilateral X shaped band of nerve fibers connecting optic nerves & tracts.
- **Size :** Width ⇒ **12** mm From before backwards ⇒ **8** mm
- **Site :** Situated at the junction of the anterior wall & floor of third ventricle
- **Relations:**

- **Anteriorly**
  - *Anterior cerebral arteries*
  - *Anterior communicating artery* + optic groove of the sphenoid bone

- **Posteriorly**
  - Below ⇒ ***Tuber cinereurn*** from which extends the ***pituitary infundibulum*** (stalk) (hypophysis cerebri).
  - Above ⇒ *3rd ventricle*

- **Laterally**
  - *Internal carotid arteries* (as it assends between between optic nerve & optic tract after piercing the cavernous sinus)
  - *Anterior perforated substance*

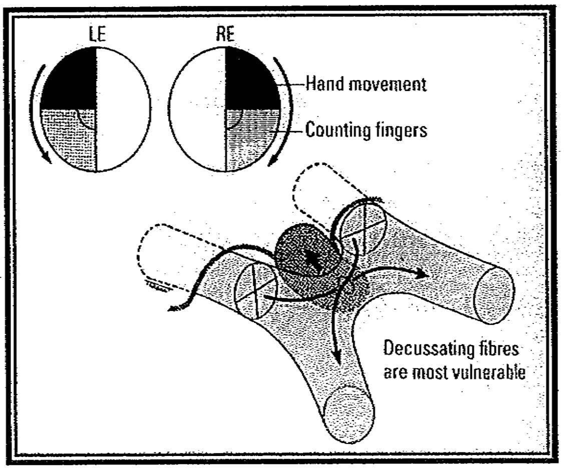
- **Superiorly** ⇒ *3rd ventricle* (the chiasma forms the floor of the optic resess of the ventricle)
  Lamina terminalis

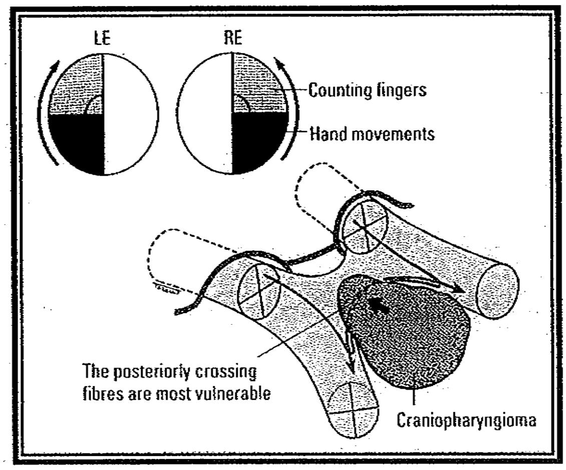
- **Inferiorly**
  - *Sella Turcica* *(Tuberculm sellae – Hypophyseal fossa - dorsum sellae)* & ***Diaphragma sellae***
  - *Cavernous sinus & its contents* (under the lateral edge)

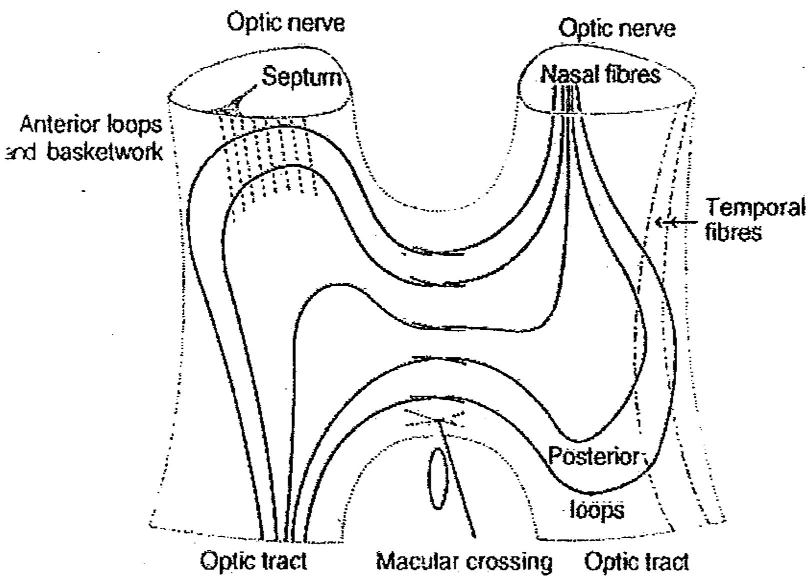
- **It is attached** by the *pia mater & arachnoid* **to** the *dorsal surface of the diencephalon*

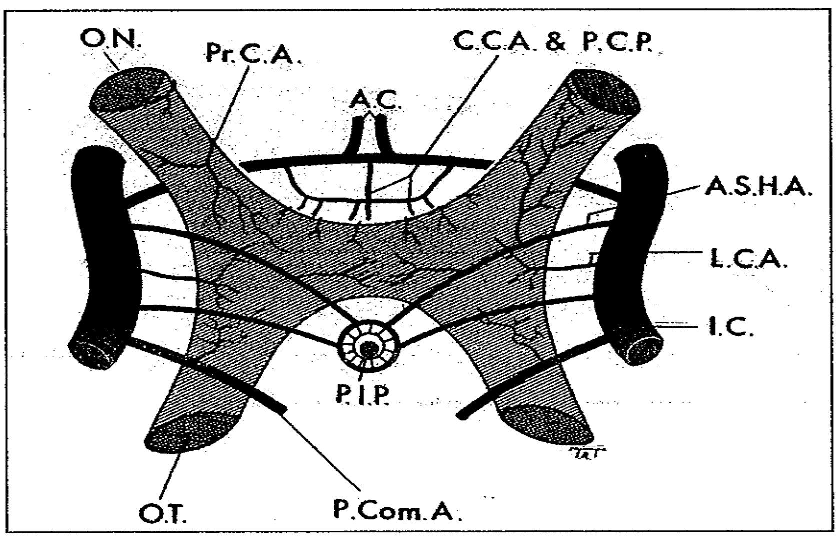
Anatomical variations:

- **Central chiasm:** (80%) → lies centrally (directly above the sella) → pituitary tumours will involve the chiasm first.
- **Prefixed chiasm:** (10%) → lies more anteriorly (over the tuberculum sellae) → pituitary tumours involve the optic tracts first.
- **Postfixed chiasm:** (10%) → lies more posteriorly (over the dorsum sellae) → pituitary tumours involve the optic nerves first.


LE
RE
Hand movement
Counting fingers
Decussating fibres are most vulnerable


LE
RE
Counting fingers
Hand movements
The posteriorly crossing fibres are most vulnerable
Craniopharyngioma


Optic nerve
Optic nerve
Septum
Nasal fibres
Anterior loops and basketwork
Temporal fibres
Posterior loops
Optic tract
Macular crossing
Optic tract


O.N.
Pr.C.A.
C.C.A. & P.C.P.
A.C.
A.S.H.A.
L.C.A.
I.C.
P.I.P.
O.T.
P.Com.A.

□ Arrangement of Nerve fibers inside the chiasma.

⇒ **Lower nasal fibres** traverse the chiasm **low & anteriorly** → Most vulnerable to damage from expanding pituitary lesions → upper temporal quadrants Field defects occur first.

The inferonasal fibres ***loop forwards*** into the proximal part of the ***contralateral optic nerve***, before passing posteriorly into the inferomedial part of optic tract ***(anterior knee of Wilbrand)*** and may therefore be affected by lesions affecting the posterior part of the optic nerve.

⇒ **Upper nasal fibres** traverse the chiasm **high & posteriorly** → involved first by lesions coming from above the chiasm (e.g. craniopharyngiomas).

The superonasal fibers ***loop backwards*** into the ***ipsilateral optic tract*** before crossing the chiasma & passing posteriorly to the superomedial part of contralateral optic tract

⇒ **Macular fibres** decussate at the **center** of the chiasm to the contralateral optic tract.
N.B. Temporal Macular fibers don't decussate

⇒ **Temporal fibers** Pass uncrossed to the ipsilateral optic tract (upper temporal above lower temporal)

□ Blood supply:

- **Pial plexus** (supplied by branches of ICA)
  - → **Anterior cerebral a.** (supply the superior aspect)
  - → **Superior hypophyseal a.**
  - → **Anterior communicating a.**
  - → **Posterior communicating a.**

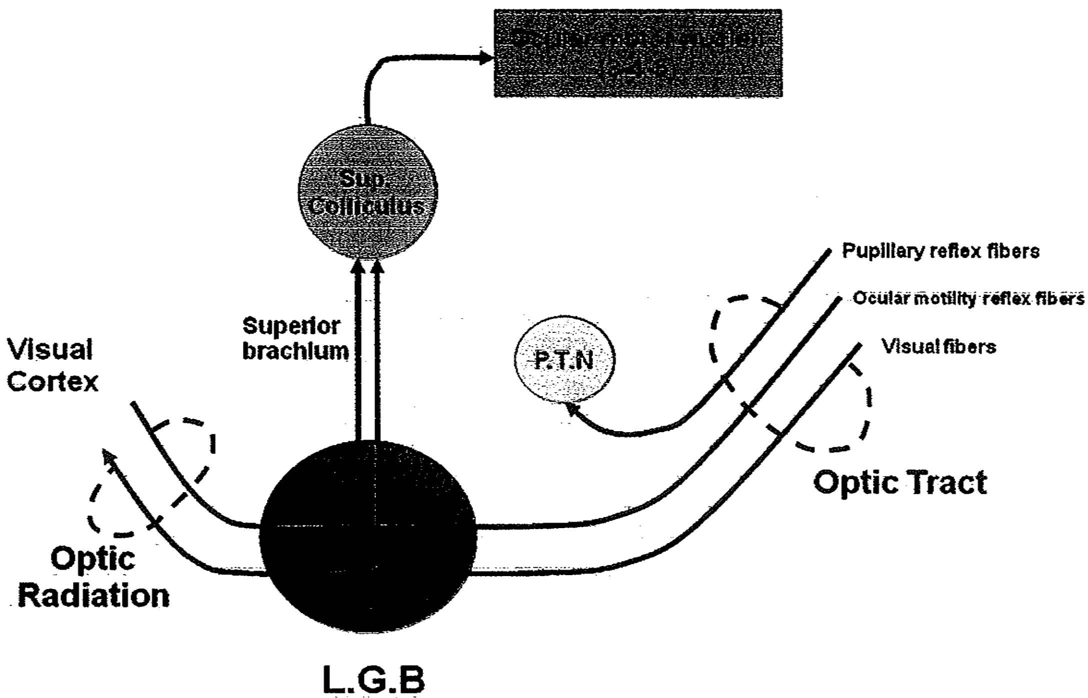
N.B. Venous drainage ⇒ Basilar veins + Anterior cerebral veins.

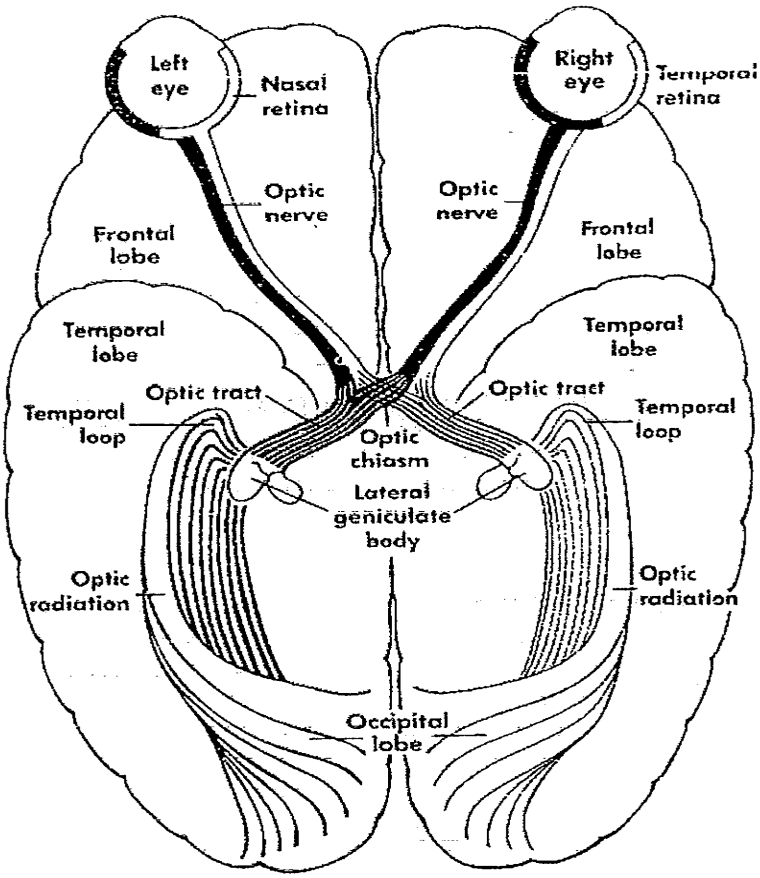
□ Applied anatomy

⇒ Compression

- From below → Pituitary tumours ⇒ ***Lower nasal*** fibers are the most affected first.
- From above → Craniopharyngioma ⇒ ***Upper nasal*** fibers are the most affected first.

> **N.B.** All post chiasmal lesions will produce **homonymous hemianopia** except lesion at the **anterior aspect of calcarine sulcus** (receives fibers from contralateral nasal retina only) ⇒ **Contralateral temporal crescentic defect.**


Sup. Colliculus
Superior brachium
Visual Cortex
Optic Radiation
L.G.B
P.T.N
Pupillary reflex fibers
Ocular motility reflex fibers
Visual fibers
Optic Tract


Left eye
Nasal retina
Right eye
Temporal retina
Optic nerve
Optic nerve
Frontal lobe
Frontal lobe
Temporal lobe
Temporal lobe
Optic tract
Optic tract
Temporal loop
Temporal loop
Optic chiasm
Lateral geniculate body
Optic radiation
Optic radiation
Occipital lobe

Optic Tract

- **Definition:** Part of the visual pathway connecting the chiasm to the lateral geniculate body. (integrated with the substance of the inferior aspect of the cerebrum)

- **Structure:** It is composed of ***axons from ganlion cells*** of the nasal retina of the opposite side and the temporal retina on the same side.

Course and relations

- The optic tract sweeps laterally, encircles the hypothalamus posteriorly (in the ventral wall of the third ventricle).
- Winds around the ventrolateral aspect of the ventral portion of the midbrain.
- Axons terminate in
  - ⇒ ***Lateral geniculate body*** (the majority of axons → subserving vision)
  - ⇒ *Superior quadrigeminal brachium* to the ⇒ ***superior colliculi*** (reflex ocular movements) → sensitive to moving visual stimuli and may direct the eyes and the head towards a visual stimulus.
  - ⇒ ***Pretectal nuclei*** (pupillary constriction).

Arrangement of nerve fibers:

- Lower retinal fibers ⇒ Lateral
- Upper retinal fibers ⇒ Medial
- Macular fibers ⇒ Dorso lateral (in a wedge shaped area)

N.B. As the tract pass posteriorly it undergoes inward twist → upper retinal fibers become ***medial***, and lower retinal fibers become ***lateral***.

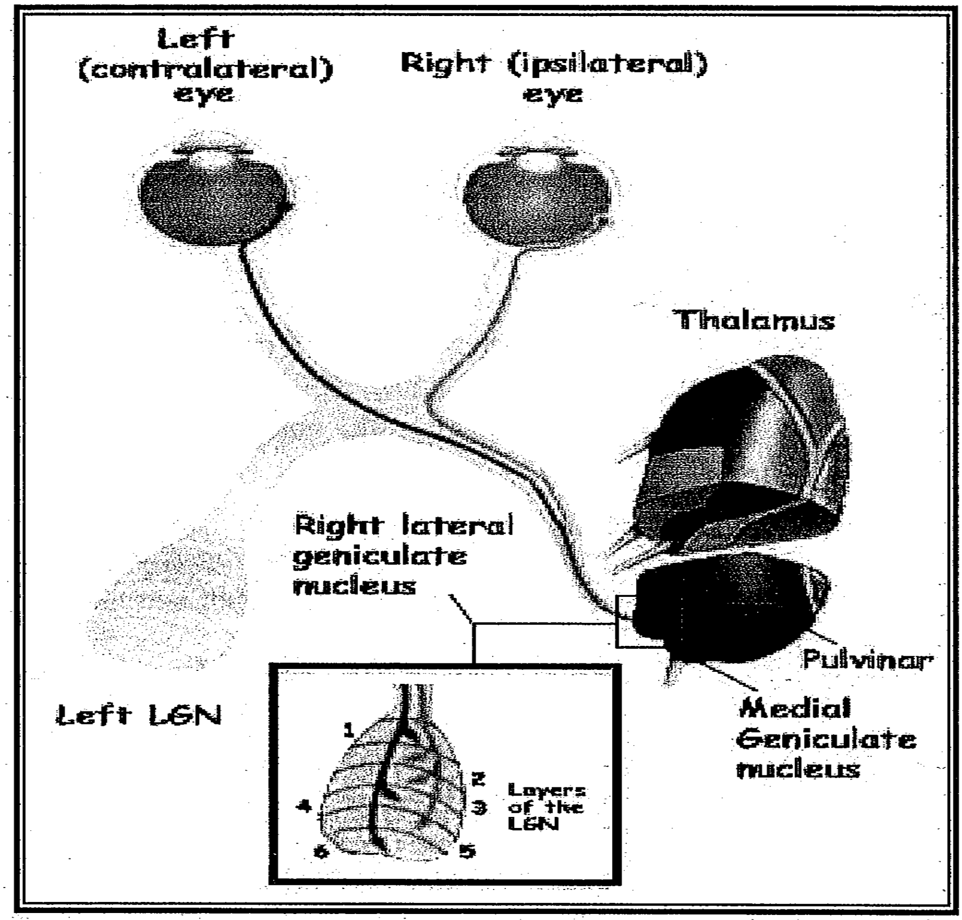
Blood supply

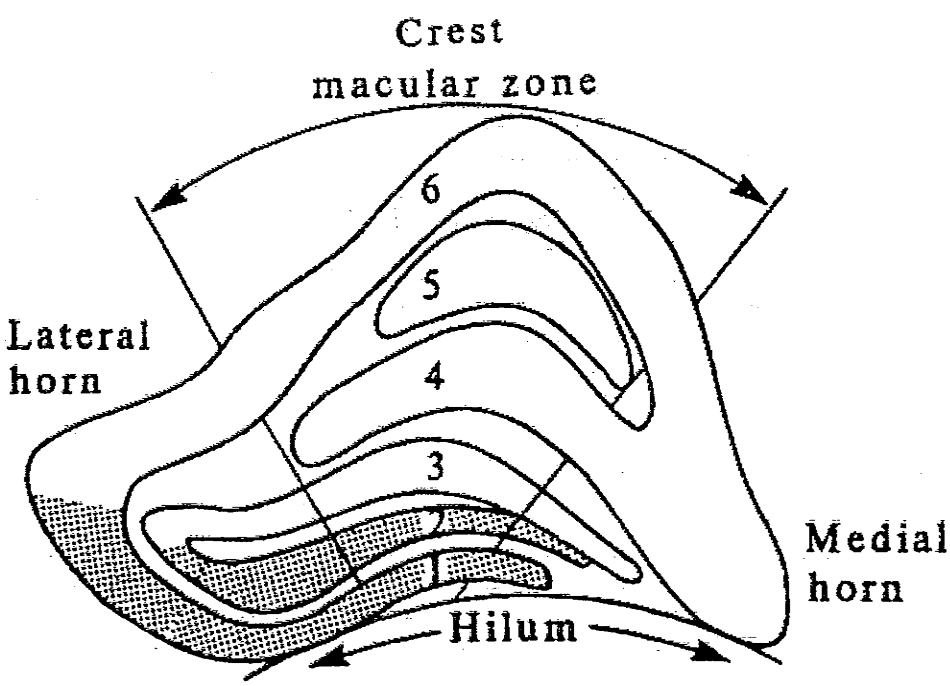
- **Pial plexus** (receives branches from)
  - → **Anterior choroidal a.**
  - → **Posterior communicating a.**
  - → **Middle cerebral a.**

N.B. in obstruction of anterior choroidal → No hemianopia, because of overlap of blood supply between anterior choroidal & posterior cerebral arteries.

Applied anatomy:

- **Contralateral Hemianopia**: Caused by complete unilateral division of any part of the visual pathway behind the chiasma.
- **Wernick's hemianopic pupillary reaction**:
  - The pupils doesnt react when a narrow pencil of light is thrown on the blind ½ of the retina, but they react if it falls on the seeing portion.
  - It differentiate between causes of *Hemianopia*
    - ⇒ ***Optic tract*** lesion → reaction is +ve
    - ⇒ Lesion ***behind optic tract*** (after separation of the pupillary and visual fibers) → reaction is -ve


Left
(contralateral)
eye
Right (ipsilateral)
eye
Thalamus
Right lateral
geniculate
nucleus
Pulvinar
Left LGN
Medial
Geniculate
nucleus
1
2
3
4
5
6
Layers
of the
LGN


Crest
macular zone
6
5
4
3
2
1
Lateral
horn
Medial
horn
Hilum

Lateral Geniculation Body

- **Definition & Site:** Small ovoid swelling on the *Lateral part of the undersurface of the pulvinar of thalamus*. (lateral to the medial geniculate body)

- **Connections:**
  - *Visual fibers*: Axons of ganglion cells that carry visual impulses.
  - *Visual cortex*: by axons of the cells of the LGB (through optic radiation)
  - *Superior colliculus*: by the *superior brachium* (formed by nerve fibers that dont terminate in the LGB but pass to the superior colliculus & the pretectal nucleus)

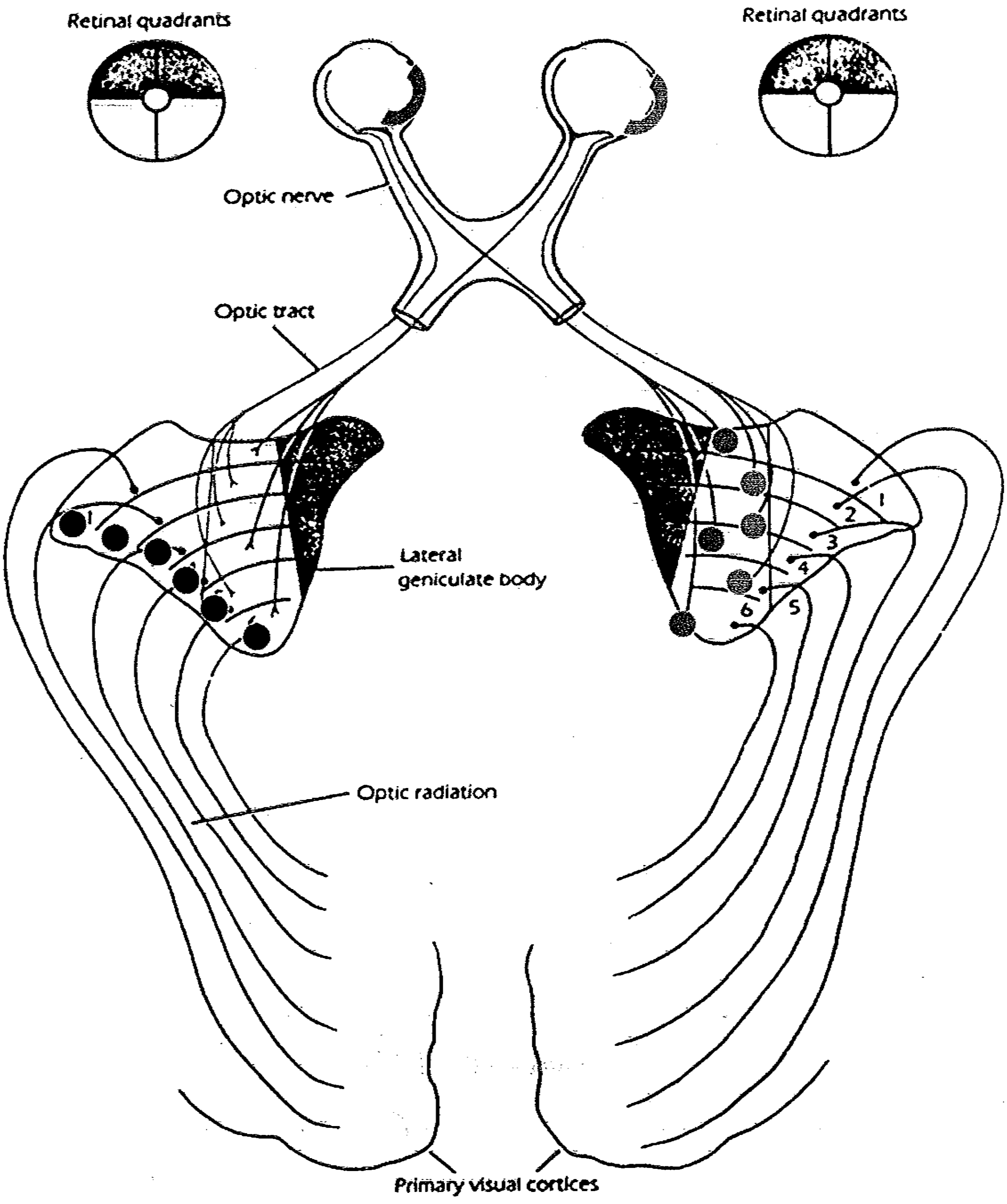
- **Relations :**
  - Anteriorly → ***Optic tract***.
  - Posteriorly → ***Hippocampal convolution***.
  - Laterally → ***Internal capsule***.
  - Medially → ***Medial geniculate body***.
  - Posterolaterally → Inferior horn of ***lateral ventricle***.
  - At a higher level → the LGB is a part of the pulvinar with following relations
    - Laterally → ***Wernick's area***
    - Medially → ***Medial geniculate body***

Superior colliculus

Afferent → (1) from optic tract (via superior brachium) optic tract → LGB → superior brachium
(2) from occipital cortex (via optic radiation) cortex → optic radiation → LGB → superior brachium
(3) Spino-tectal tract (getting sensory fibers from the spinal cord)

Efferent → (1) Ocular nuclei (2) tecto-spinal tract → spinal cord.

- **Gross:**
  - **Coronal section**
    - Rounded ***Apex*** or crest (superiorly)
    - ***Body***.
    - Medial and lateral ***horns***.
    - ***Inferior rim*** (incomplete)
    - ***Hilum*** (inferiorly & extends to the posterior part of the nucleus)
  - **Saggital section**
    - ***Optic tract*** fibers → divide into superior & inferior layers → enclose the LGB forming it's capsule.
    - ***Optic radiation*** fibers → pass from the dorsal portion of LGB → Wernick's area


Retinal quadrants
Retinal quadrants
Optic nerve
Optic tract
Lateral geniculate body
Optic radiation
Primary visual cortices

☐ **Structure:** 1 million nerve cells forming dorsal & ventral nucleus.(rudimentary in human)

Dorsal nucleus (main lateral geniculate nucleus)

- Composed of six cellular layers (1-6) of ***grey matter*** beginning at the hilus and continuing towards the dorsal portion of the nucleus, & separated by ***white bands*** of optic nerve fibers.
  - ***Magnoecellular*** laminae (Ventral layers 1 & 2) ⇒ Cells are larger and more uniform in size and shape ⇒ carry signals sustain the detection of movement and flicker.
  - ***Parvocellular*** laminae (Remaining 4 layers) ⇒ carry signals sustain perception of color, texture, shape, and fine stereopsis.
- Representation of retina in dorsal nucles of LGB
  - Axons from ***temporal*** retina of the same eye → synapse in layers 2, 3, 5 [temporal → two+3 = 5]
  - Axons from ***nasal*** retina of the opposite eye → synapse in layers 1, 4, 6 [Opposite → One+4 = 6]
  - Axons from ***inferior*** retina → synapse in the **lateral** portion.
  - Axons from ***superior*** retina → synapse in the **medial** portion.
  - Axons from ***fovea*** → located **posteriorly**.
  - **Central** visual fibers are represented in all six layers. (no bilateral representation of the macula)
  - **Peripheral** axons are represented in the 2 magnocellular layers & in 2 parvocellular layers

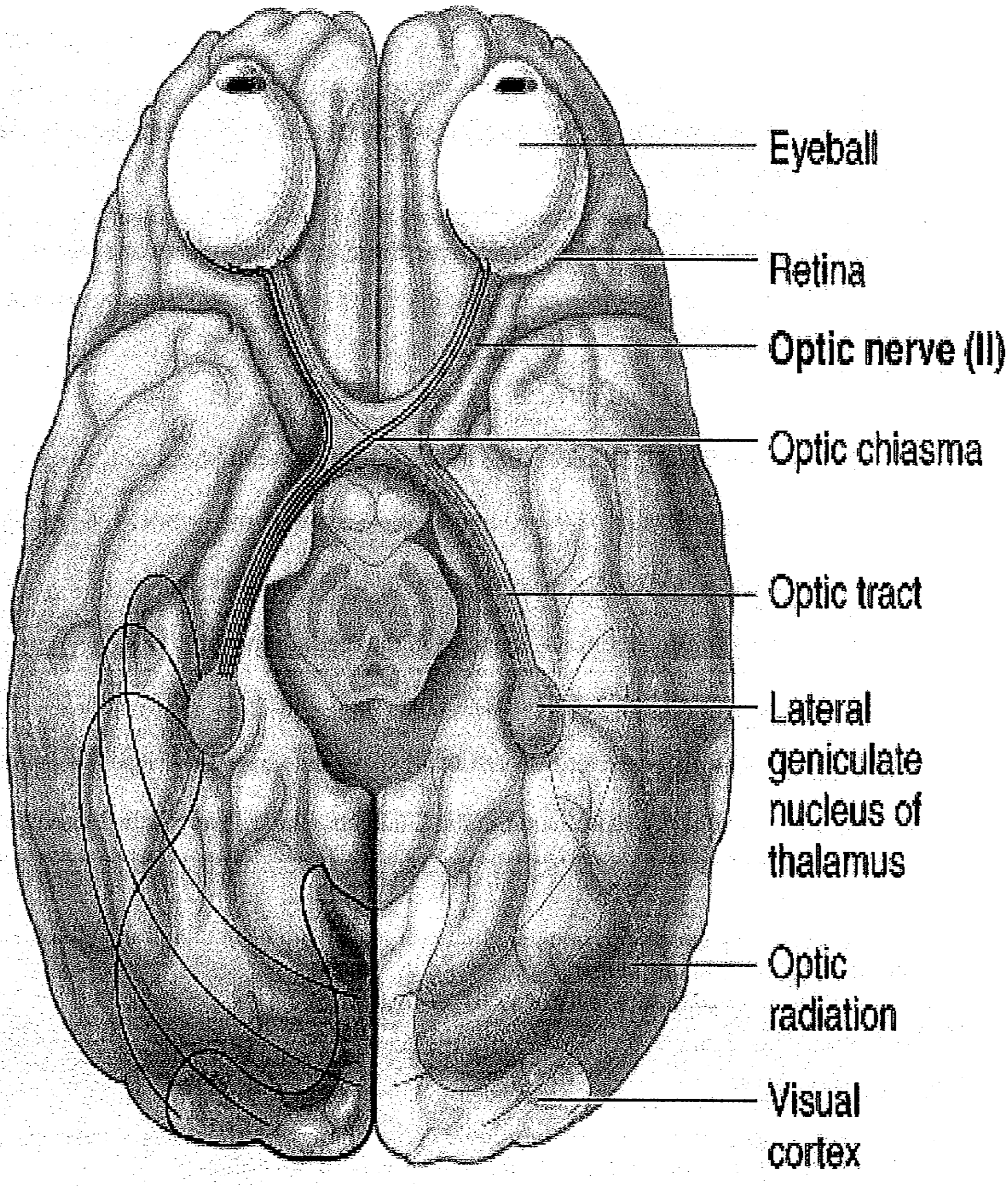
> **N.B.**
> - Each LGB cell synapse with one ganglion cell axon, but each ganglion cell axon can synapse with more than cell in the LGB.
> - Fusion doesnt occur at the level of LGB

☐ **Blood supply:**

- ***Anterior choroidal a.*** (branch of middle cerebral a.) ⇒ **Antero-lateral** aspect. (representing the inferior homonymous quadrants of the retinae)
- ***Thalamogeneculate a.*** (branch of posterior cerebral a.) ⇒ **Postero-medial** aspect (representing the the superior homonymous quadrants of the retinae)
- **Lateral choroidal arteries.**

☐ **Applied anatomy :**

- Distruction of the LGB
  ⇒ ***Contralateral Homonymous hemianopia*** + *Profound contralateral sensory loss*
  ⇒ pulvinar of thalamus must be involved


Eyeball
Retina
Optic nerve (II)
Optic chiasma
Optic tract
Lateral geniculate nucleus of thalamus
Optic radiation
Visual cortex

Optic Radiation

(Geniculo-calcarine tracts)

- **Definition:** formed of nerve fibers that originate from the nerve cells of the LGB and ends in primary visual cortex

Course & Distribution of axons:

- Axons from the cells in the ***lateral aspect*** of the LGB
  representing the ***Lower retinal*** quadrants (superior visual field)
  Form the **lower** portion of the radiation
  ♣ pass anteriorly around the tip of the **temporal** horn of the lateral ventricle to form the temporal (inferior) loop of Meyer → ♣ swing posterior (in the retrolentiform part of internal capsule) to terminate in
  ⇒ the ventral (inferior) lip of the calcarine fissure.

Damage to the axons in this loop ⇒ superior homonymous quadrantic field defects.

- Axons from the cells in the ***medial aspect*** of the LGB
  representing the ***Upper retinal*** quadrants (inferior visual field)
  Form the **upper** portion of the radiation
  ♣ pass directly posterior through the **parietal** lobe (in the retrolentiform part of internal capsule) to terminate in
  ⇒ the dorsal (superior) lip of the calcarine fissure.

- ***Macular fibers*** are separated into *upper* & *lower* fibers ⇒ that is why one may get a quadrantic field defect with a sharp horizontal border.

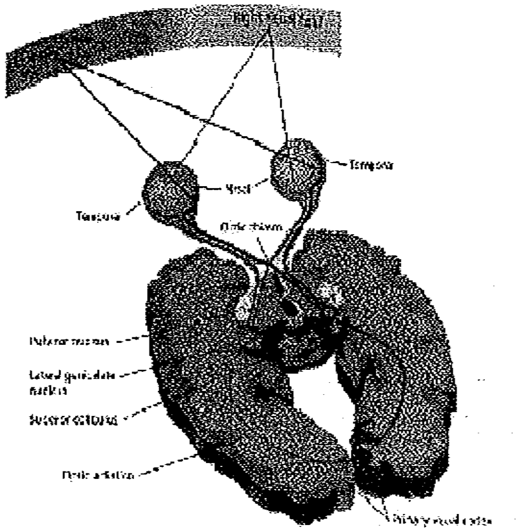
The axons emerging from the cells of the lateral geniculate body have exact correspondence in each eye so that a lesion in them causes exactly similar visual field defects in each eye ***(homonymous congruous defects)***

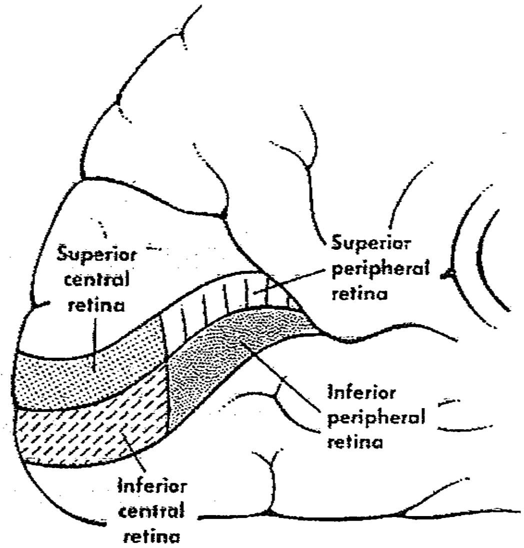
Relation:

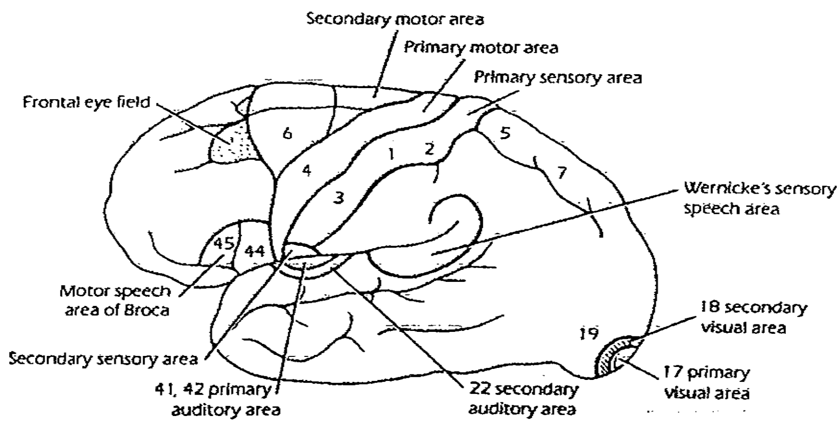
- *Deep* to the ***middle temporal gyrus*** (in the white matter of the cerebral hemisphere)
- *Lateral* to temporal and occipital ***horns*** of the ***lateral ventricle*** (lie in the lateral sagital stratum, separated from the wall of the lateral ventricle by the medium sagital stratum)

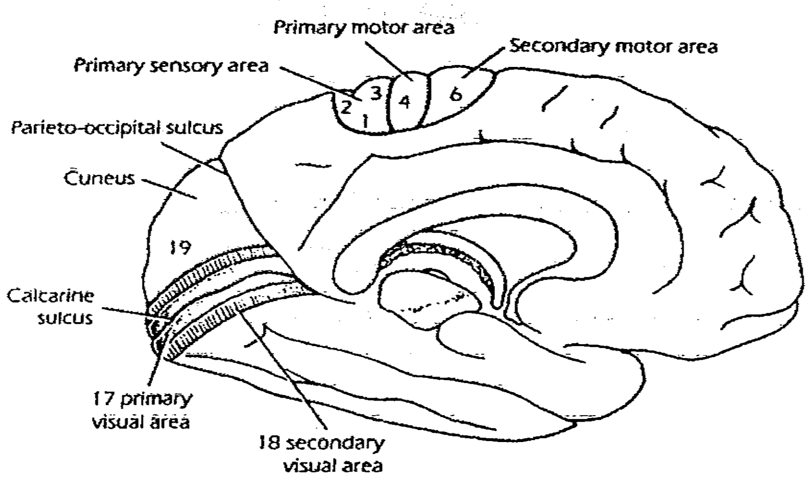
Blood supply:

- Anterior portion → ***Anterior choroidal a.*** (branch of ICA)
- Posterior portion
  → Deep optic branch of ***Middle cerebral a.***
  → Calcarine branch of ***Posterior cerebral a.***




Superior central retina
Superior peripheral retina
Inferior peripheral retina
Inferior central retina


Secondary motor area
Primary motor area
Primary sensory area
Frontal eye field
6
1
2
5
4
7
3
Wernicke's sensory speech area
45
44
Motor speech area of Broca
18 secondary visual area
19
Secondary sensory area
17 primary visual area
41, 42 primary auditory area
22 secondary auditory area


Primary motor area
Secondary motor area
Primary sensory area
2
3
1
4
6
Parieto-occipital sulcus
Cuneus
19
Calcarine sulcus
17 primary visual area
18 secondary visual area

Visual Cortex

Primary visual cortex (area 17)

- **Location**: on the ***medial surface*** of the hemisphere
  - At the walls of the ***deep calcarine sulcus***
  - Extends onto the cortex above (till the cuneate sulcus) and below (till the collateral sulcus).
  - Posteriorly it extends till the occipital pole and a small portion of the postero-lateral aspect of the pole.
  - Anteriorly it extends till the parieto-occipital sulcus.
- **Structure**:
  - Called the **Striate cortex** because of the presence of ***Myelinated fibers*** of geniculo-calcarine fibers (white line or striae of Gennari) in ***grey matter***. (in the 4th layer)
  - Thinner (1.5 mm) than other cortical regions. But the cell population is greater (1/10 of cortical cells)
  - 6 layers
    - → Cells of laminae II & III ⇒ project to ⇒ secondary visual cortex.
    - → Cells of lamina V ⇒ project to ⇒ Superior colliculus
    - → Cells of lamina VI (pyramidal cells) ⇒ project to ⇒ L.G.B.
    - → Cells of lamina IV (stellate cells) ⇒ receive afferent from ⇒ L.G.B. [Thickest layer]
- **Representation of Retinal part on the primary visual cortex**:
  - **Superior** retina (inferior visual field) is represented on → **superior** wall of calcarine sulcus.
  - **Inferior** retina (superior visual field) is represented on → **inferior** wall of calcarine sulcus.
  - **Central** retina is represented on the → Tip of the **posterior** pole.
  - **Peripheral** retina is represented on the → more **anteriorly**.
  - Right half of visual field is represented in the left visual cortex & vice versa.

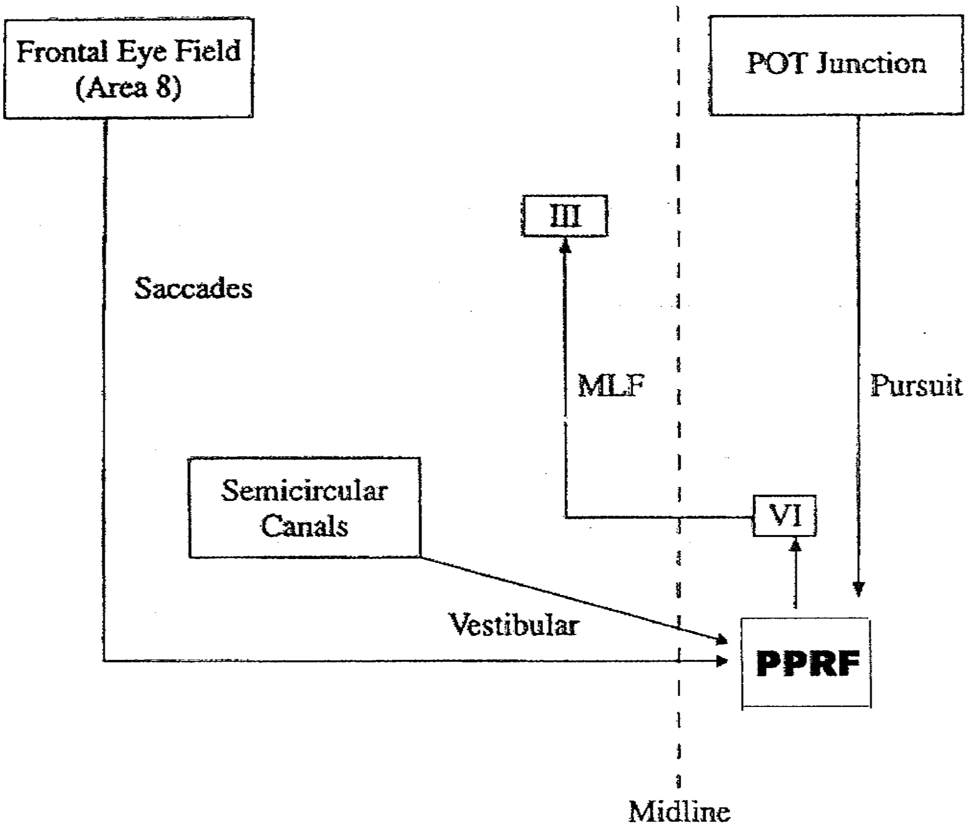
> ***Macular sparing***
> (destruction of the occipital lobe on one side seems not to affect all of the central retinal fibers)
> 1) **Double blood supply** (middle & posterior cerebral) → **incomplete destruction**
> 2) **Extensive macular representation** in the cortex
> 3) **Minute changes in visual fixation.**

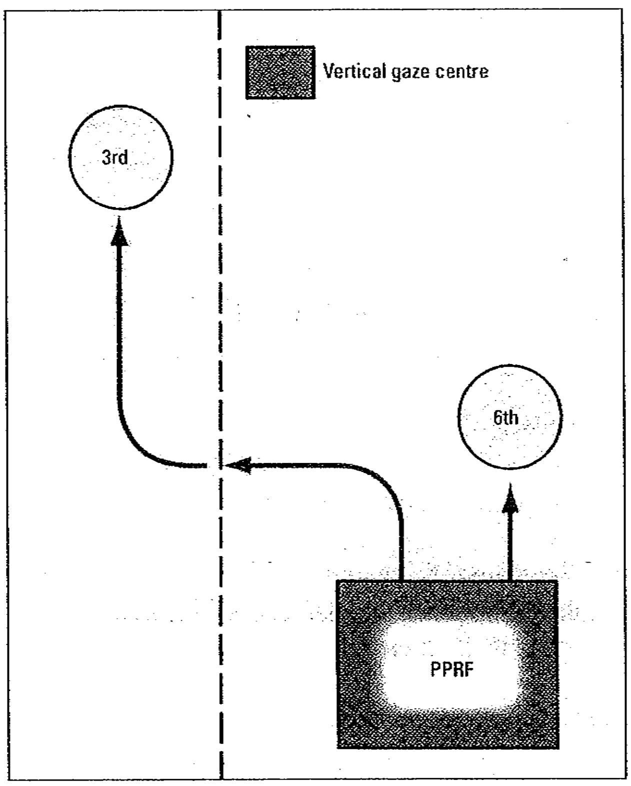
Secondary visual cortex (areas 18 & 19)

- **Location:** Surrounding area 17 on the medial & lateral surfaces of the hemisphere.
- **Structure:**
  - Non-striate
  - Receive afferent fibers from ⇒ Area 17 + other cortical areas + thalamus
- **Function:**
  - Relate visual information received by area 17 to past visual experience ⇒ interpretation of what one is seeing.
  - Integrate the 2 halves of the visual fields (by means of commissural fibers that cross the middle line in the splenium of the corpus callosum)
  - Sensory motor eye coordination.

Blood supply:

⇒ ***Posterior cerebral a.***
⇒ ***Middle cerebral a.*** (assist at the anterior end of the calcarine sulcus + lateral surface of posterior pole)


Frontal Eye Field
(Area 8)
POT Junction
III
Saccades
MLF
Pursuit
Semicircular
Canals
VI
Vestibular
PPRF
Midline


Vertical gaze centre
3rd
6th
PPRF

□ Other cortical oculomotor areas:

- **<u>Occipital eye field</u>** (Parieto-occipito-temporal junction)
  - Site → secondary visual area
  - Stimulation → conjugate deviation of both eyes to the same side.
  - Function → ***<u>Pursuit movement</u>*** (*reflex* <u>smooth eye movement</u> when following an object)

- **<u>Frontal Eye Field</u>** (Area 8 of frontal lobe)
  - Site → From <u>Facial area of the paracentral gyrus</u> into the <u>middle frontal gyrus</u>.
  - Stimulation → conjugate deviation of both eyes to the opposite side.
  - Function → ***<u>Saccades movement</u>*** (*voluntary* <u>fast eye movement</u>)
  - Connection → to the <u>superior colliculus</u> → tectobulbear fibers → ocular motor nuclei

- **<u>Sensory speech area of wernicke</u>**
  - Site → <u>Superior temporal gyrus</u> of the *<u>Dominant hemisphere</u>*
  - Function → *<u>Understanding of written & spoken language</u>* + enable person to <u>read</u> a sentense, <u>understand</u> it & <u>say</u> it loud.
  - Connection:
    - ⇒ Receives fibers from → **Visual cortex & auditory cortex**
    - ⇒ **Brocas area.**

The Medial (Posterior) Longitudinal Fasciculus

□ Connects:

- Motor cells of the ***<u>oculomotor</u>*** complex to each other
- Nuclei of the ***<u>trochlear</u>*** and ***<u>abducent</u>*** cranial nerves.
- The supranuclear ***<u>centers for gaze</u>*** (horizontal gaze center in PPRF)
- The ***<u>cerebellum</u>***.
- Sensory nuclei of the ***<u>trigeminal</u>*** nerve.

□ Function: ⇒ coordinate conjugate movements of the eyes.

□ Abducent nuclei → Have 2 types of neurones

1- One type whose axons innervate **<u>ipsilateral</u> LR muscle.**

2- Another type whose axons decussate to the **<u>contralateral</u> MLF → MR nucleus.**

- ⇒ So, on looking to the left side → the left LR contracts, & the right MR muscle does the same.
- ⇒ A <u>lesion in an abducent nucleus</u> thus causes a failure to move both eyes to the right or to the left. A <u>lesion in an abducent nerve</u> affects only the lateral rectus muscle of that side
- ⇒ <u>Internuclear ophthalmoplegia</u>: (Anterior lesions of the medial longitudinal fasciculus) ⇒ convergence is normal but, on attempts to turn the eyes laterally, the adducting eye does not pass beyond the midline and there is a coarse nystagmus of the abducting eye.

N.B. There are no known **Vertical gaze center**, but the **rostral ipsilateral nucleus of MLF** is involved in generating vertical saccades

It receives input from:

1- PPRF.
2- Frontal eyefield.
3- Vestibular nuclei.

It sends output to:

1- Third cranial nerve nucleus → SR, IR, IO
2- Fourth cranial nerve nucles → SO

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